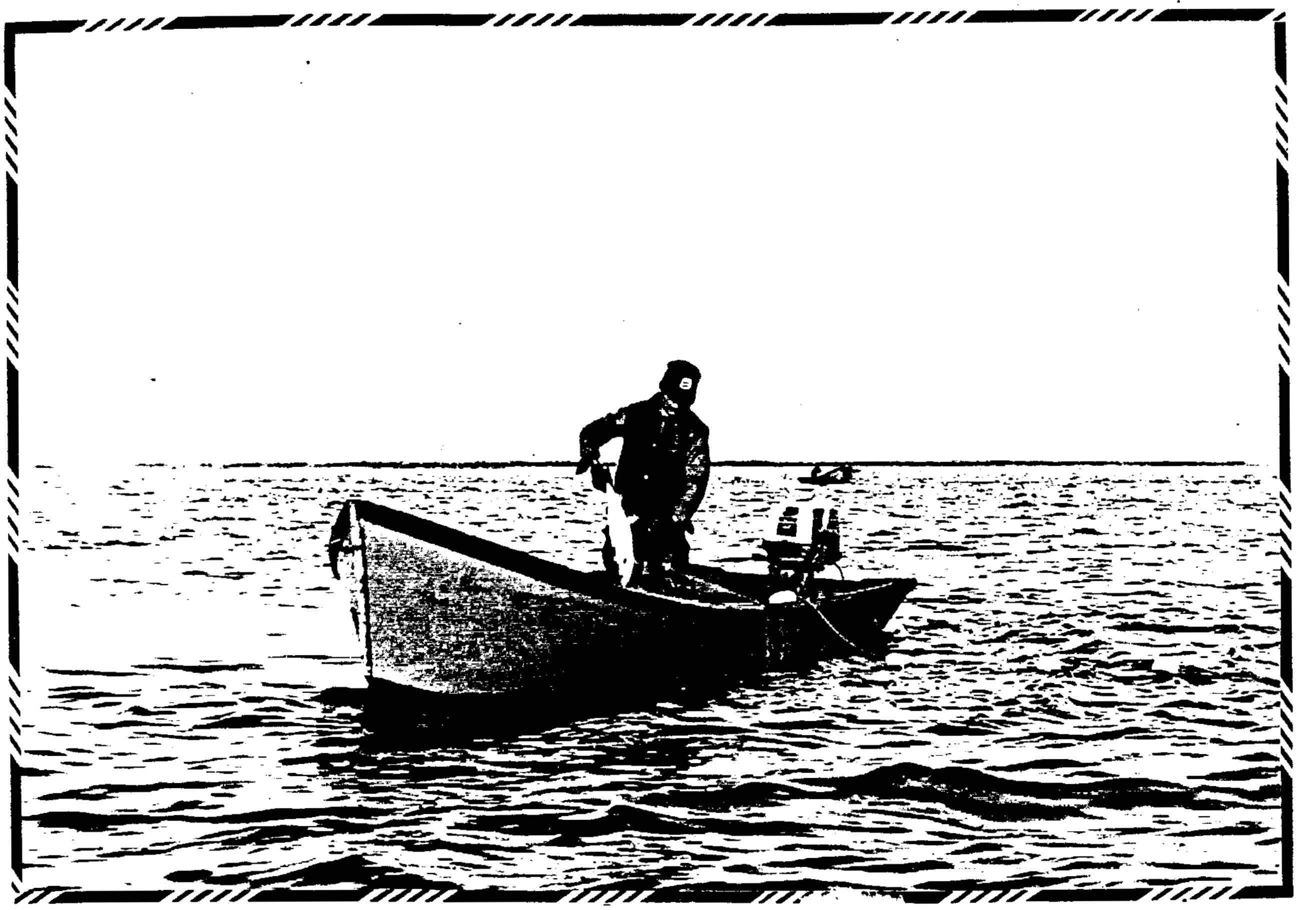
RIR Number 1J87-1

SOUTHEAST ALASKA INTER-DIVISIONAL SOCKEYE SALMON PROGRAM REVIEW

April 16 & 17, 1987

Juneau, Alaska



Regional Informational Report No. 1J87-1

Sponsored by:

The Southeast Region

Commercial Fisheries Division

Alaska Department of Fish and Game

FOREWORD

A Southeast Alaska inter-divisional, inter-agency sockeye salmon program review/workshop, the first of its kind for the region, was held April 16 & 17, 1987, at the Super 8 Motel in Juneau. It was intended to be a review of "who's doing what" with sockeye in the region, and, as originally envisaged in the early planning stages, it was to be a small but diverse gathering of biologists to discuss their respective studies and exchange ideas. It soon became apparent, however, that the size and scope of the problems, the studies, and the interest in sockeye in Southeastern was much more extensive than any of us had imagined. As a result, the program quickly grew to 13 speakers and attracted 34 invited guests. The presentations were well prepared, well received, and they generated a good deal of discussion and noteworthy recommendations for further focus.

This document is a compilation of the presentations and a summary, in memo form, of the General Discussion. The latter also summarizes the participants' wishes and recommendations for subjects for additional attention and future sockeye salmon workshops. An attempt to include the more salient points of discussion following each presentation was unsuccessful due to audio tape and recorder difficulties.

The review/workshop generated a good deal of enthusiasm for continued focus on the sockeye resource in Southeast Alaska; it is important that we maintain the momentum.

Gary Gunstrom
June 1987
Juneau, Alaska

SOUTHEAST ALASKA INTER-DIVISIONAL SOCKEYE SALMON PROGRAM REVIEW

HELD APRIL 16-17, 1987
AT THE SUPER 8 MOTEL IN JUNEAU, ALASKA

Final Agenda (Revised)

THURSDAY

8:15-8:30	Introduction (Gunstrom)
	Presentations
8:30-9:00	Management (Ingledue)
	1. Historical perspective 2. Current management 3. Management problems and needs (data gaps)
9:00-12:15	Research
	* Commercial Fisheries Division regional research review (Bergander)
BREAK	* U.S./Canada stock separation review (Hoffman) * Overview of scale pattern analysis (Van Alen) * Bristol Bay sockeye management program (Eggers)
LUNCH 12:15-1:30	
1:30-5:00	* Rearing habitat in the lower Taku River (Heifetz) * Distribution and utilization of the Taku River by sockeye salmon (Eiler). * Prevalence of zero check sockeye in S.E. Alaska (McPherson). * Use of brain parasites for sockeye identification (Moles).
BREAK	* F.R.E.D.D. limnological studies (Koenings) * Disease control (IHN) (Meyers) * Auke Lake studies (Taylor)

FRIDAY

8:15-10:15	Hatchery Production/Enhancement
	* FREDD (Haddix)
BREAK	* NSRAA (Bachen) * SSRAA (Johnson)
10:30-12:00	General Discussion - Where Do We Go From Here?

Southeast Alaska Inter-Divisional Sockeye Salmon Program Review

April 16-17, 1987

Attendants

Name	Agency
Gary Gunstrom	ADF&G/CF
Phil Doherty	ADF&G/CF
Bruce Bachen	NSRAA
Jon Heifetz	NMFS
Dave Waite	ADF&G/FREDD
Dave Barto	ADF&G/FREDD
Mike Haddix	ADF&G/FREDD
Kathleen Jensen	ADF&G/CF
Ben Van Alen	ADF&G/CF
Andy McGregor	ADF&G/CF
Andy Smoker	ADF&G/CF
Carol Denton	ADF&G/FREDD
K Koski	NMFS
Steve Hoffman	ADF&G/CF
Fred Bergander	ADF&G/CF
Ray Staska	ADF&G/CF
Joe Muir	ADF&G/CF
Don Ingledue	ADF&G/CF
Keith Johnson	SSRAA
Doug Eggers	ADF&G/CF
Glen Oliver	ADF&G/CF
Norma Sands	ADF&G/CF
Adam Moles	NMFS
Scott McPherson	ADF&G/CF
John Eiler	NMFS
Bonita Nelson	NMFS
Ted Meyers	ADF&G/FREDD
Jeep Rice	NMFS
Malin Babcock	NMFS
Mitch Lorenz	NMFS
Jerry Taylor	NMFS
Jeff Koenings	ADF&G/FREDD
Carol Coyle	ADF&G/FREDD

ADF&G - Alaska Department of Fish & Game
CF - Commercial Fisheries Division
FREDD - Fisheries Rehabilitation, Enhancement, and Development Division
NMFS - National Marine Fisheries Service
NSRAA - Northern Southeastern Regional Aquaculture Association
SSRAA - Southern Southeastern Regional Aquaculture Association

INTRODUCTION

INTRODUCTION

Gary Gunstrom
Region I Research Supervisor
Commercial Fisheries Division
Alaska Department of Fish and Game

Welcome! I wish to welcome you all to this Regional sockeye salmon interdivisional, interagency program review.

With our present day focus on pink salmon as the dominate species in the Region, and chinook salmon concerns receiving most of the publicity, we may tend to forget that sockeye was the species of principal interest in the early days of commercial salmon fishing in S.E. Alaska; the other species, in some documented cases, being piled on the ends of the cannery docks and processed if and when the cannery crews could get to them after first addressing the sockeye that had been offloaded. On occasion, there just wasn't time, and the other species spoiled and were shoved off the end of the dock.

Well, we've come downhill a long ways since then, and sockeye harvests now only constitute about half of their former abundance.

Though we've never historically devoted much funding to sockeye research in the Region, it has become abundantly clear since the start of the U.S./Canada program 5 years ago that we know very little about the sockeye resource in S.E. Alaska. We only recently learned of mainstem spawning stocks in the Chilkat, Taku and Stikine Rivers, its only recently that we discovered how large the McDonald Lake run can be, and it took a weir to discover that. And, there are other examples involving south-end migration patterns, run timing, interceptions, and harvest rates.

The last five years, and the last three years in particular, have shown a proliferation of interest in sockeye research in the region. So much so, by so many different entities and agencies, that its really been difficult to keep it all in perspective. And, thus, the reason for this mini-workshop/program review. There are some really exciting research projects on-going or planned for the Region, and we are going to hear about them during the next day and a half.

There are several objectives that I wish for us to address during and following our time together. The first two, those of increasing our mutual awareness of sockeye management needs, and current and planned investigations, will come as a natural result of our meeting; there are others that I plan to identify for us during the course of our discussions, such that they can be dealt with during our concluding session on Friday.

Well, then, that's enough introduction, lets get on to the really good stuff!

MANAGEMENT

REVIEW OF CURRENT SOUTHEAST ALASKA SOCKEYE MANAGEMENT

Don Ingledue
Juneau Area Management Biologist
Division of Commercial Fisheries
Alaska Department of Fish and Game

A. General Resource Information and Stock Status.

1. There are approximately 120 sockeye producing systems in the Southeast Alaska Region extending from Dixon Entrance to Yakutat. Most of the systems are relatively small with spawning capacities of generally less than 50,000 and very few over 100,000 fish.

2. Northern British Columbia sockeye salmon stocks contribute to to Southeast Alaska fisheries, particularly in southern Southeastern Alaska and the transboundary rivers.

3. Formal spawning escapement goals have not been established for a majority of the stocks.

4. An indication of historical and current stock status may be the commercial salmon harvest record (see Fig. 1). Current sockeye salmon catches are depressed from historical levels. The peak historical harvest of approximately 3.5 million sockeye salmon occurred in 1914 and the the high decade average of 2.9 million fish occurred during the same time period. The current decade average (1980's) has been approximately 1.4 million fish. This is well below high historical levels, however, it is is an improvement over recent year levels, and is the highest decade average since the 1930's.

5. As most stocks are relatively small, rebuilding the overall resources to historical levels will be a difficult task.

6. Sockeye salmon resources are a major consideration of the U.S. Canada Pacific Salmon Treaty. The treaty sets harvest limits in the drift gillnet fisheries in Districts 1, 6, 11, the District 4 purse seine fishery and specifies cooperative management in the Alsek River.

B. Resource Users

1. Sockeye salmon are harvested by commercial, sport, and subsistence users in fisheries ranging from the outer coastal areas to in-river. In numbers of fish, the commercial harvest far exceeds the sport and subsistence take (see Fig. 2).

2. The commercial net fisheries harvest, by far, the biggest share of the annual harvest (see Fig. 3 and 4). Of these the drift gillnet fisheries currently account for highest share of the commercial take, followed by the seine and set gillnet fisheries.

3. The annual harvest in the subsistence fishery is relatively small, however, as much of the harvest activities are concentrated on relatively small stocks, the subsistence harvest has impacted some local stocks.

C. Purse Seine Fishery Management

1. The purse seine harvest of sockeye salmon is considered an incidental take except for the District 4 (Noyes Island) and Necker Bay and Redfish Bay along the outer coastal areas of Baranof Island in District 13.

2. Inseason management is minimal and is not based on inseason assessments of spawning escapements.

3. The current purse seine pink salmon management approach of limiting fishing early in the season has benefited sockeye salmon spawning escapements, which are more available for harvest early in the season. This is particularly true in northern Southeast Alaska, however, the same benefits have occurred in the southern fishing districts.

4. The major seine harvest occurs in the District 4 fishery. The District 4 seine fishery is regulated to meet the terms of the U.S. Pacific Salmon Treaty, which specifies an average annual four year harvest of 120,000 sockeye salmon prior to statistical week 31 (Late July). This is accomplished by regulating fishing time in relation to fishing effort and salmon availability. In recent years a majority of the District 4 sockeye salmon harvest has occurred during intensive pink salmon seining after statistical week 31 and during August. The reduced reduced early season fishing time, necessary to meet the treaty obligations, may be benifitting escapement levels of Alaskan stocks.

5. Although most purse seine management is for harvesting pink salmon, the availability of sockeye salmon (as "money fish") is a major factor for some seiners in selecting where to fish.

D. Set Gillnet Fishery Management

1. Sockeye salmon predominate the Yakutat set gillnet summer fishing season. It is primarily an in-river fishery.

2. Inseason management is accomplished primarily through the analysis of fishery performance information (ie CPUE). Inseason enumeration of spawning escapement is difficult in most of the individual fisheries. However, good and timely escapement information is available for the Situk River and East River fisheries and is relied upon for inseason management.

3. The poor production being realized for the Situk River is a current major managment concern.

E. Drift Gillnet Fishery

1. There are six distinct drift gillnet fisheries in Southeast Alaska. They all occur in the ocean waters. The harvest of sockeye salmon is the major overall drift gillnet management concern during the summer season.

2. Inseason management is based on fishery performance information and inseason escapement enumeration where available. The availability of management information is variable among the areas.

3. The harvest is generally highly mixed stock. Recent advances in stock separation technologies have provided improved management capabilities.

4. Inseason analysis of stock separation information is being used for management in Districts 6, 8, 11, and 15.

5. The drift gillnet fleet has become very mobile and moves quickly among the various gillnet areas in response the availability of sockeye salmon.

F. Management Needs

1. Continue and expand current efforts to enumerate sockeye spawning escapements both for inseason management and post season evaluation.

2. Develop methodoligies to establish sockeye salmon spawning escapement goals.

3. Continue stock separation work in major fishing areas.

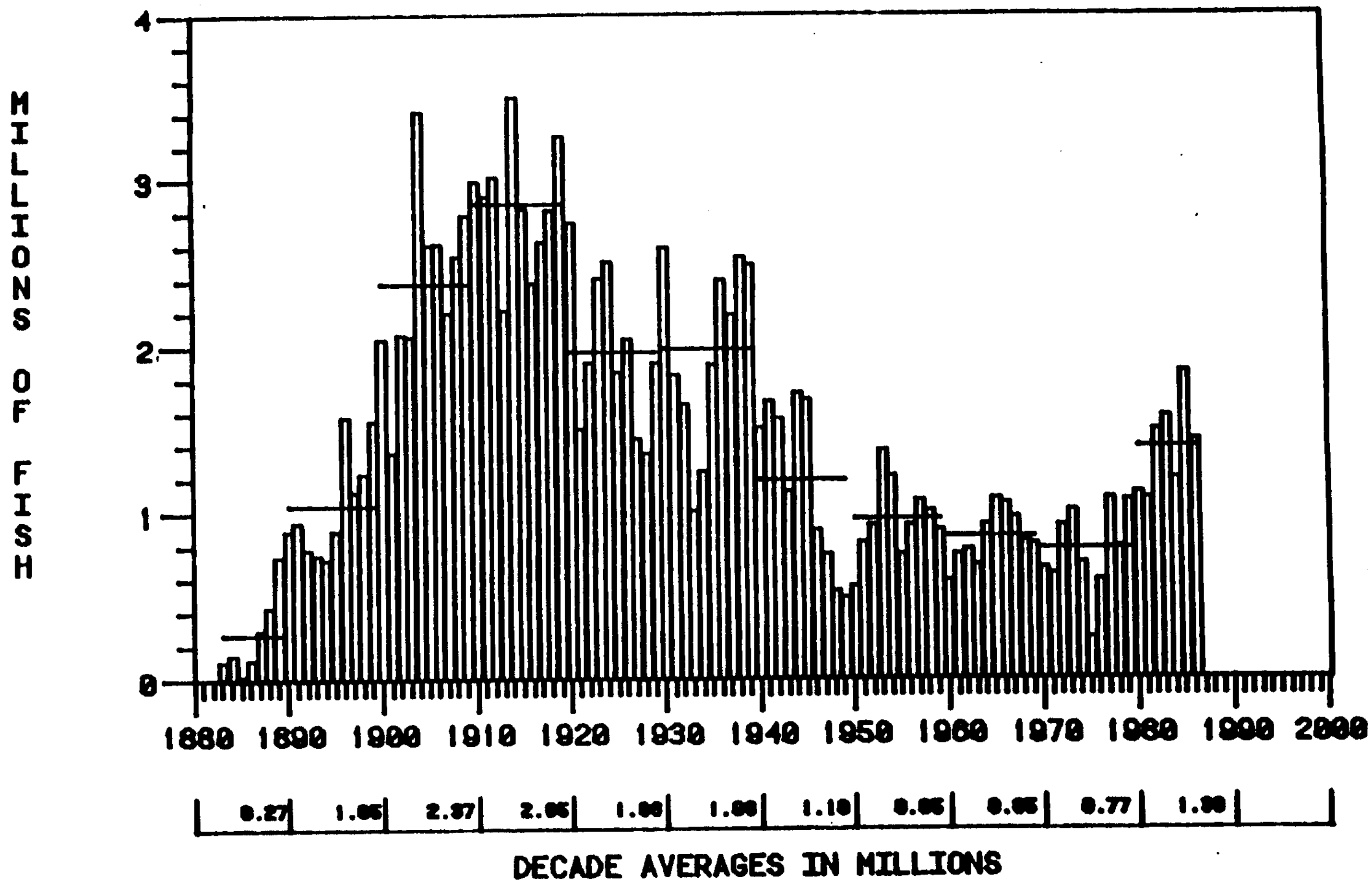


FIGURE 1 . SOUTHEAST ALASKA REGION HISTORICAL COMMERCIAL SOCKEYE SALMON CATCHES BY 29 Commercial Gear Totals , 1883 TO PRESENT. PREPARED: ADF&G 11/21/86.

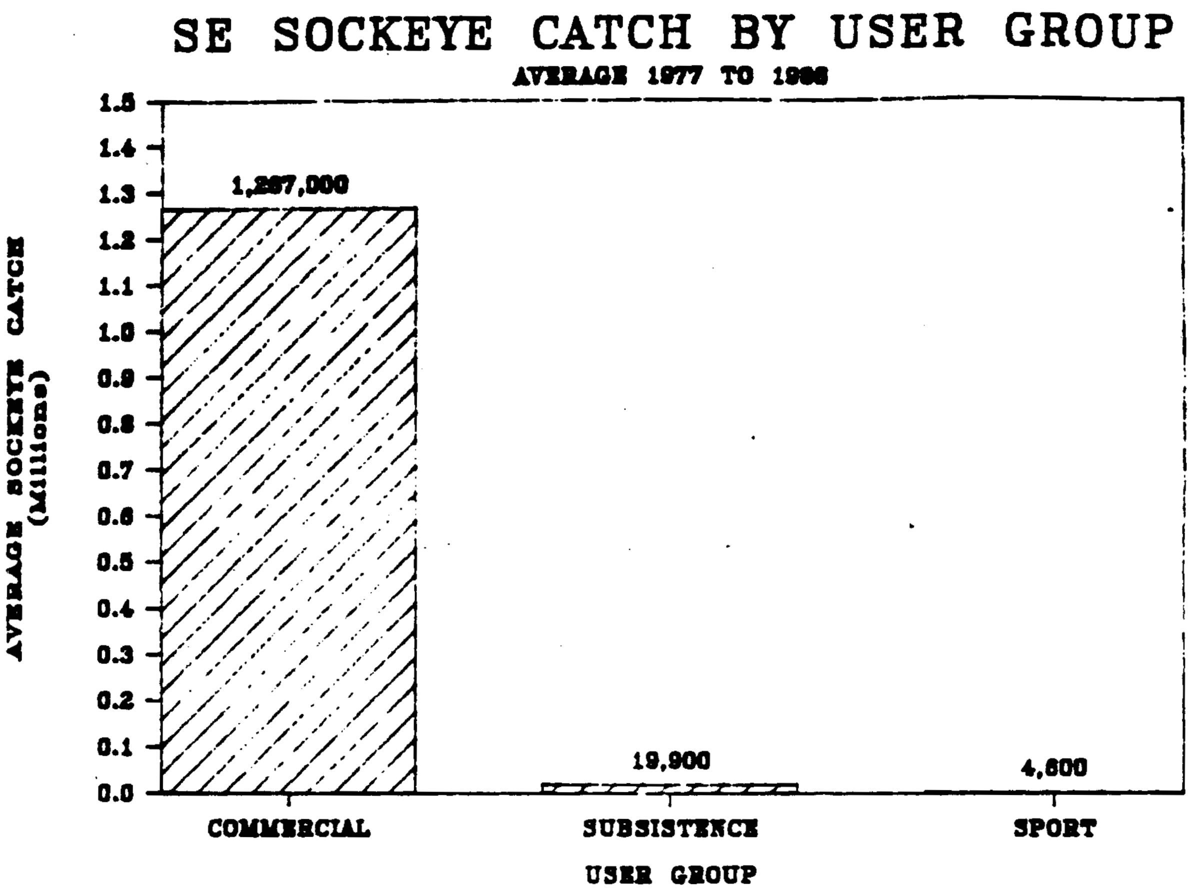


Figure 2. Southeast Alaska Region Sockeye Salmon Average Annual Harvest by Major User Group, 1977-86.

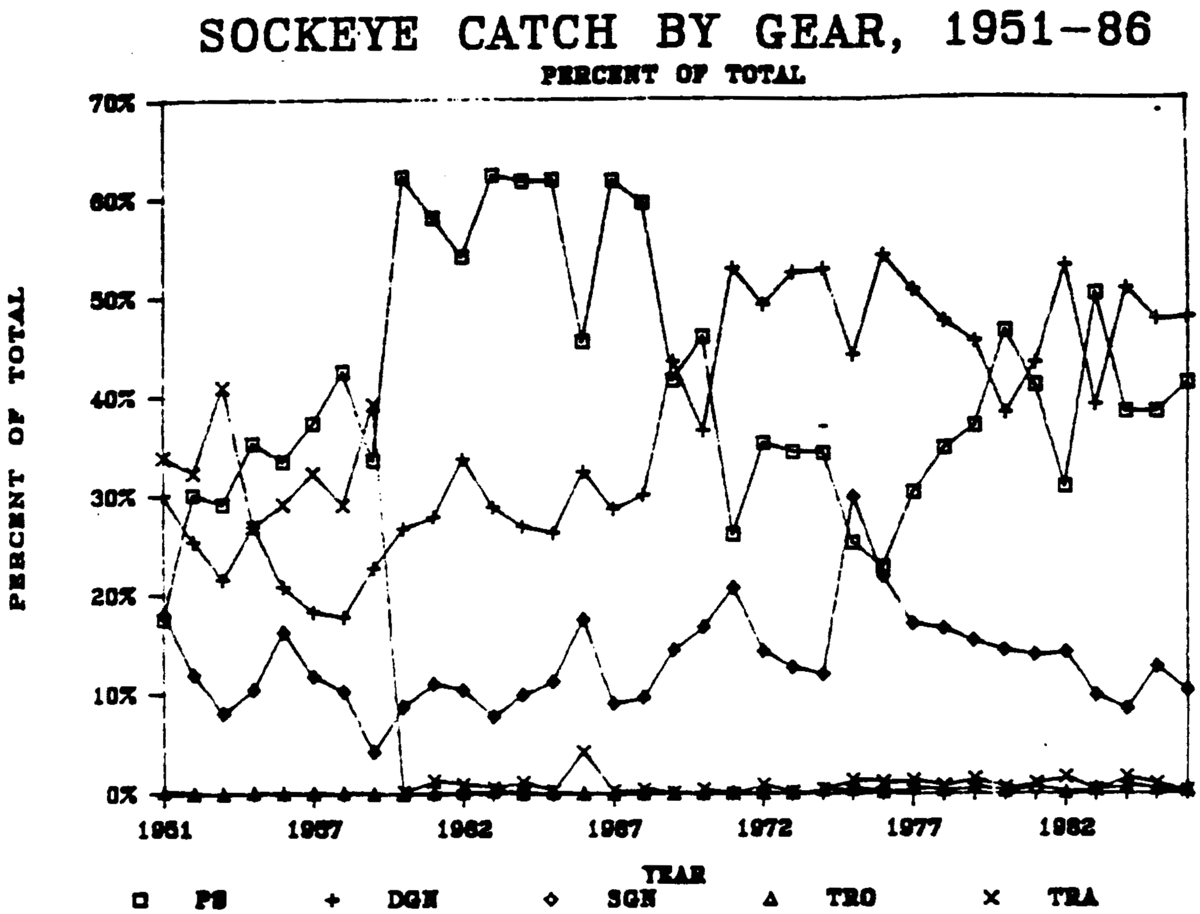


Figure 3. Southeast Alaska Region Commercial Sockeye Salmon Catch by Gear in Percent of Total, 1951-86.

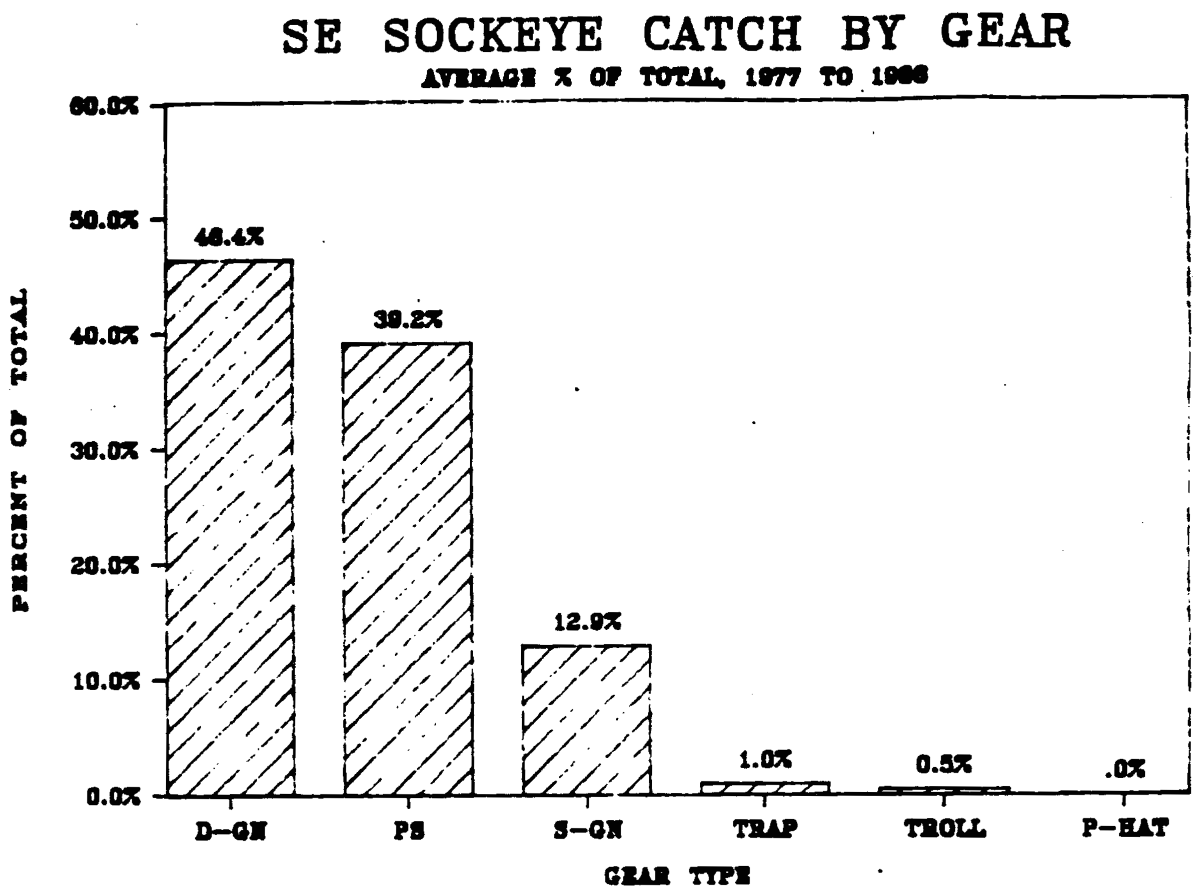


Figure 4. Southeast Alaska Region Commercial Sockeye Salmon Catch by Gear, Average Percent of Total, 1977-86.

RESEARCH

SOCKEYE SALMON REGIONAL RESEARCH REVIEW

Fred Bergander
Alaska Department of Fish and Game
Commercial Fisheries Division

INTRODUCTION

The southeastern sockeye research began in 1967 as a Federally funded program under the Anadromous Fish Conservation Act. The initial program consisted of escapement enumeration at a number of weirs located throughout Southeast Alaska. Limited scale sampling was conducted at the weirs, from the commercial fisheries, and from the estuaries adjoining other sockeye systems on Prince of Wales Island.

In 1972 the program was revised to concentrate the effort on the Chilkat and Chilkoot stocks which support the Lynn Canal gillnet fishery (Figure 1). At this time it was recognized that there were substantial differences between the growth rates of Chilkat and Chilkoot smolt which were recorded in the fresh water portion of the the scales of these stocks. These biological markers provided the basis for the stock composition analysis that is presently conducted on the Lynn Canal harvest.

In 1976 a weir was constructed at the outlet of Chilkoot Lake and escapement enumeration of the Chilkoot sockeye began. Approximately $72 thousand were spent in the construction of this weir; $49 thousand were from Capital Improvement Funds.

In 1981 the Stock Biology Group became active in the Lynn Canal and a comprehensive catch sampling program was initiated. This program provided in-season estimates of the stock composition of the catch and post season analysis of the age composition of the catch and escapement. This in-season information, in conjunction with the escapement enumeration, provided relative run strength data for the Area Management Biologist to use in the regulation of the fishery. The post season age analysis provided return information from known brood year escapements that is used in the development of brood year tables.

The signing of the U.S./Canada Pacific Salmon Treaty generated new information needs related to the interception of International stocks near the U.S./Canada border and transboundary river systems. Program proposals were prepared which will provide basic data needs relative to U.S./Canada stock interceptions. Sockeye weirs located at Crescent, Speel, (Figure 2) Salmon Bay, Hugh Smith Lakes, and the Naha and Karta Rivers (Figure 3) will provide escapement, timing data and scale samples; the scale samples will be used by the Stock Biology Group to define biological markers that may be used to identify the contribution of these stocks to the various fisheries.

Other proposed studies under U.S./Canada include a microwire tagging study of the Hugh Smith and McDonald Lakes sockeye. The proposal calls for the release of 30,000 or more sockeye smolt that have had coded wire tags implanted in their heads from each system. The recovery of these fish from the fishery will provide information on the total contribution of these stocks to the fishery, determine the exploitation rates for these stocks and identify the fisheries where these stocks are intercepted. Another tagging study is proposed to assess the Alsek River (Figure 4) sockeye stocks; a feasibility study is tentatively scheduled for this season.

OBJECTIVES

1. To monitor the escapement of sockeye salmon into key spawning systems throughout Southeast Alaska.

2. To identify escapement goals for sockeye systems in Southeast Alaska.

3. To identify intercepting fisheries and interception rates of these fisheries on the various sockeye stocks.

RESULTS and DISCUSSION

Lynn Canal Studies

Escapements have been recorded at Chilkat and Chilkoot Lakes from 1967 and 1976, respectively. When Chilkoot weir was put on line in 1976, estimated escapement goals for these systems were set at 60 thousand to 70 thousand and 80 thousand to 90 thousand for Chilkat and Chilkoot, respectively. Since that time, escapement goals for both stocks have been reached or exceeded 8 of 11 years (Figures 5 and 6).

In 1981 the escapement goals to both systems were adjusted with Chilkat being increased to a range of 70 thousand to 90 thousand and Chilkoot reduced to a range of 60 thousand to 80 thousand; the goals shown in figures 5 and 6 are midpoints.

Due to the proximity of Chilkoot weir to the fishery, management was able to respond to changes in the escapement and implement the appropriate management actions. Figure 7 demonstrates the effectiveness of the management of the Chilkoot stocks; except for three years (1976, 78, and 82) management was able to come within 25% of the escapement goals, and 5 years the escapement goals were exceeded by no more than 10%. Between 1976 and 1986 Chilkat escapement goals were reached or exceeded 8 of the 11 years; however, during only 4 of the 11 years were the escapements within 20% of the escapement goals (Figure 8).

Figures 9 and 10 describe the annual escapements to Chilkat and Chilkoot Lakes, respectively in relation to their averages. The average escapement to Chilkat Lake for the period of record was approximately 63 thousand fish and Chilkoot 84 thousand. The true average escapement to Chilkat may have been higher had, during the 1967 through 1970 seasons, the weir been run beyond the 17th of September. This "early closure" may have missed the late season surge in escapement observed since 1971.

Figure 11 provides and example of the late season surge in escapement to Chilkat that limits the application of Chilkat escapement information to in-season management. By August 20 the summer season for sockeye is essentially over. Figure 11 describes the eratic nature of the arrival of the escapement at Chilkat weir and the unpredictibility of in-season escapement enumeration at Chilkat weir. Projected estimates of the escapement have been made which utilize a run model that encorporates stock composition of the catch, Chilkoot escapement and assumes reltively uniform exploitation rates for the two stocks. The model has had limited success due to what may be differential harvest rates; for example in 1986 the model projected an escapement of 50-55 thousand which included the subsistence catch. The observed escapement was approximately 23,000. A tagging study proposal has been drafted that, if found feasible, could describe more clearly the harvest rates on the two stocks and generate a more accurate projection of the in-season escapement; the limiting factor in feasibility of this study will be our ability to capture enough sockeye to tag.

Escapement goals

Escapement goals for Chilkoot and Chilkat Lakes were first estimated in 1976. The basis for these goals was the estimated rearing capacity of the respective lakes. Evaluation of the subsiquent escapements relied on the identification of returns from known brood year escapements. This has turned out to be a lengthy and time consuming process with up to 6 years elapsing to account for the return of the progeny from one brood year escapement. Begining in the spring of 1987 we will begin a limnology study of Chilkoot and Chilkat Lakes in cooperation with NSRRA and ADF&G's FRED Division. The objectives of the study are to:

1) Measure the euphotic zone and provide and in this way estimate the rearing capacity of the lakes.
2) Identify potential for enhancement.

U.S./Canada Studies

Escapement estimation studies funded by U.S./Canada have produced escapement records shown in Table 1 Snettisham weirs and Table 2 Southern Southeast weirs. The McDonald Lake escapement estimates were derived in a number of ways; basically, they were derived from foot surveys adjusted by a correction factor calculated by the FRED Division in 1981, 1983, and 1984 when they were operating a weir at that site.

In addition to the escapement enumeration being conducted at weirs, a micro-wire smolt tagging study was initiated at McDonald and Hugh Smith Lakes in 1986; the first fish to return from this release will appear as two ocean fish in 1988. Scale samples are being collected for stock identification purposes. Scale samples are being analysed by the Stock Biology Group.

SUMMARY

The collection of escapement data is providing useful information on some of our sockeye stocks, however, this information would increase in value if we knew how many fish we needed in the respective escapements to sustain a healthy population. Essentially what I'm saying is that we now need to establish escapement goals for these stocks. In January of this year I drafted a memo (attached) to Dave Cantillon listing escapement goals for a number of sockeye systems in southeast Alaska. The memo listed these goals as ranges and there were two sets of ranges, one set based on the criteria used to set the escapement goals for Chilkoot and Chilkat by the Comm. Fish Division and the other using criteria established by the FRED Division for McDonald Lake. The point is that we need a uniformly accepted method of arriving at escapement goals so when we are asked by the public what these goals are we all use the same figures.

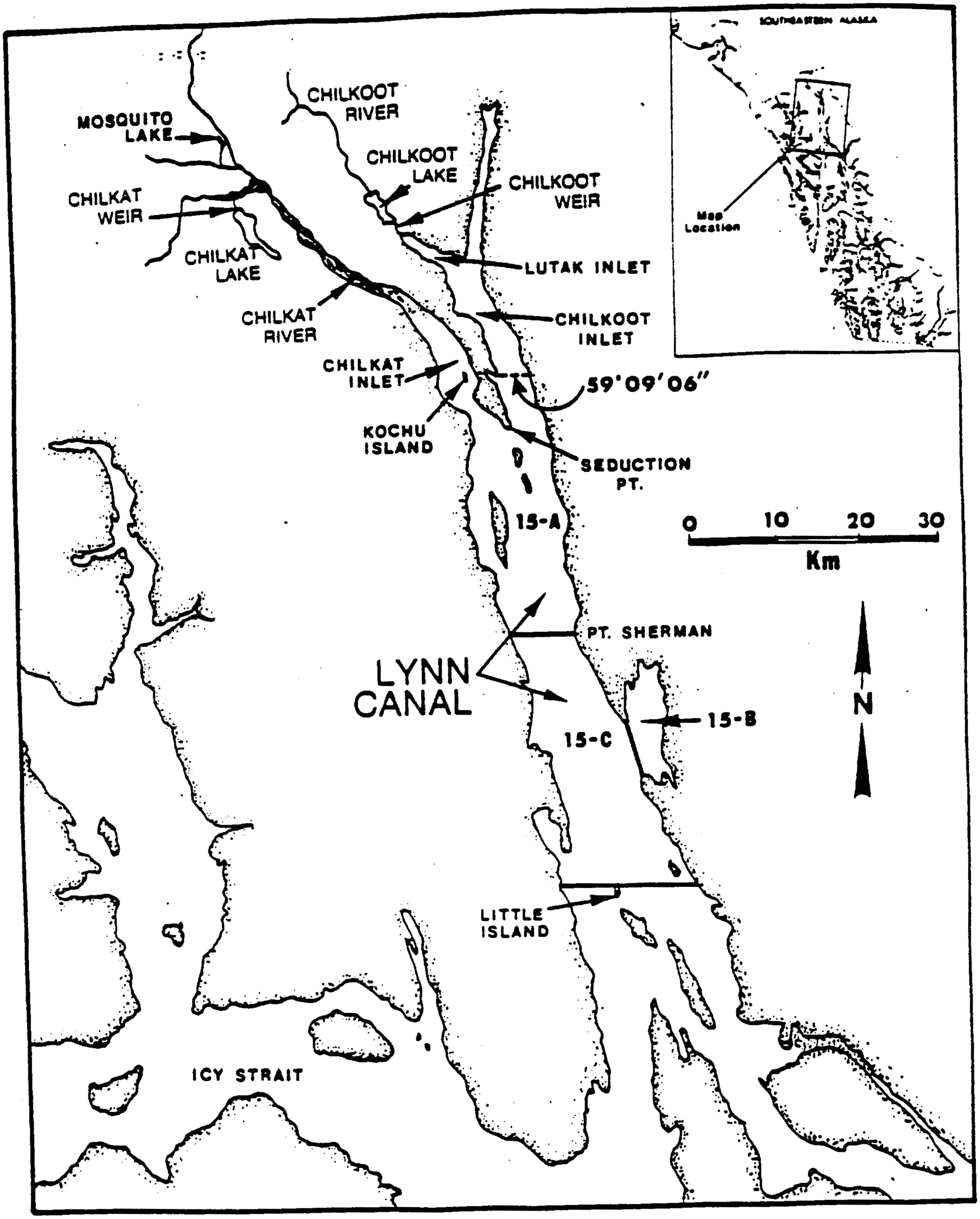


Figure 1. Lynn Canal Fishery areas and supporting sockeye salmon spawning systems, Chilkoot and Chilkat Lakes.

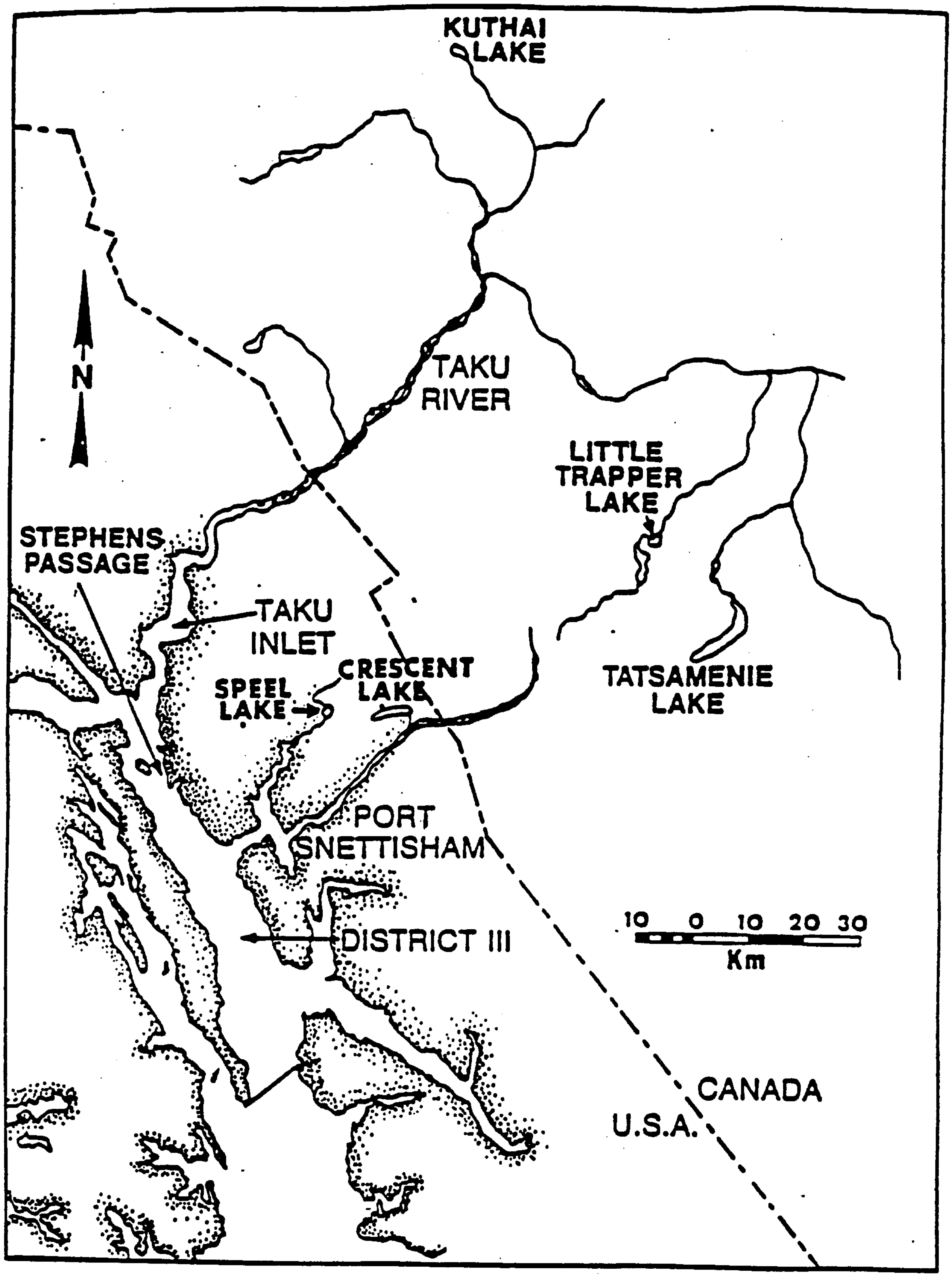


Figure 2. The Taku River and Port Snettisham sockeye salmon spawning systems.

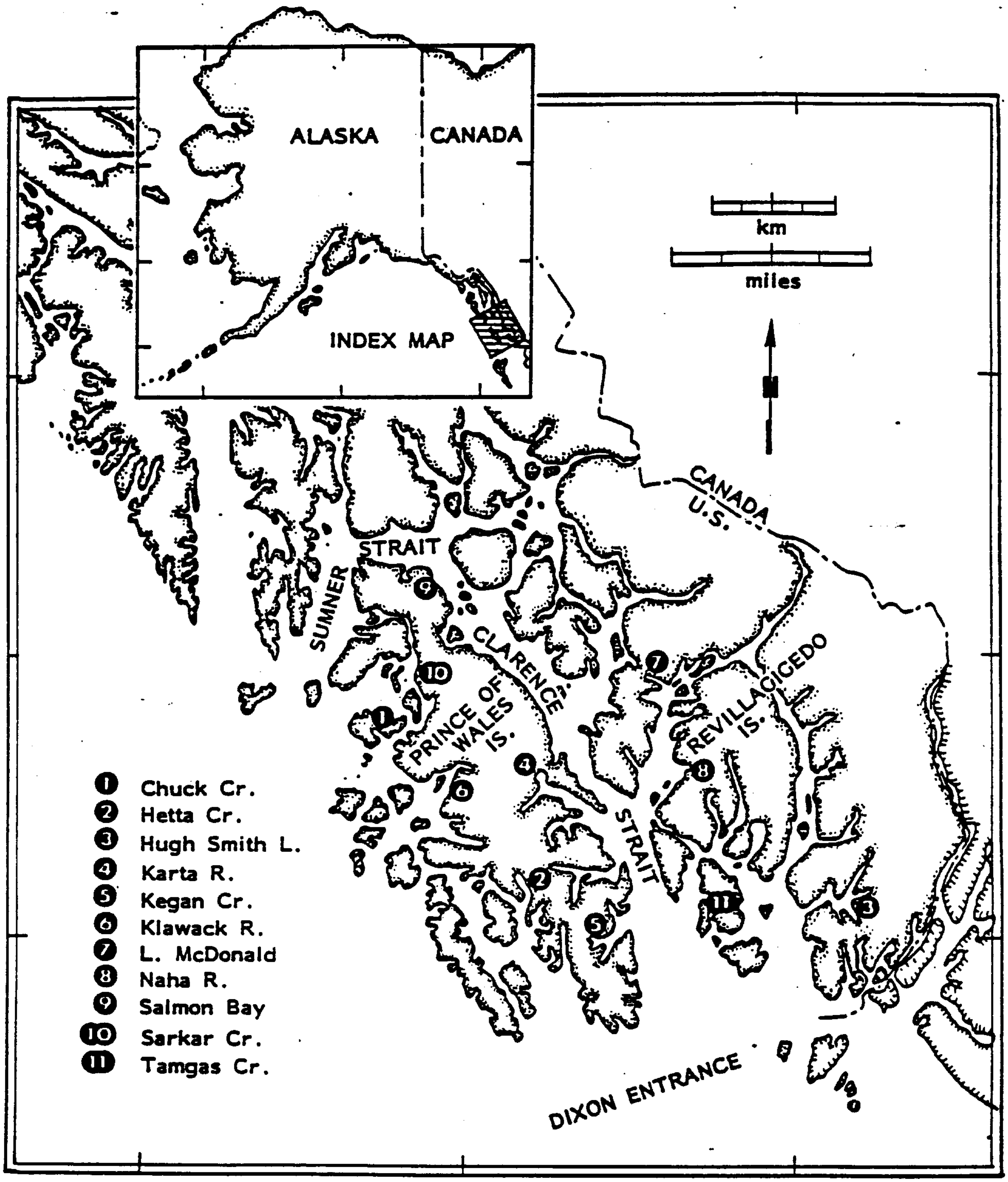


Figure 3. Location of weir sites used to record the escapement of sockeye salmon and other salmonids in the southern part of southeastern Alaska, 1982-83.

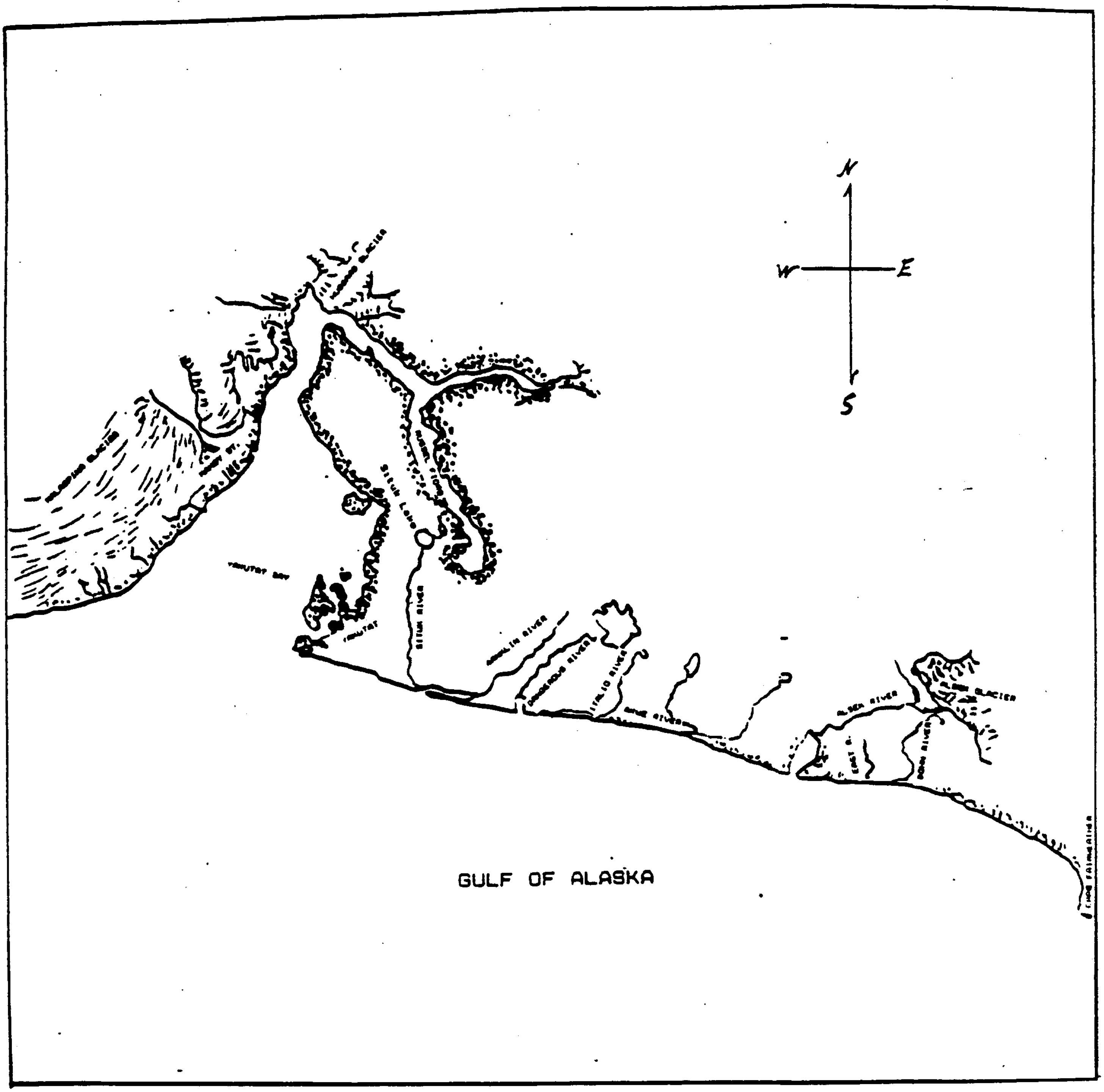
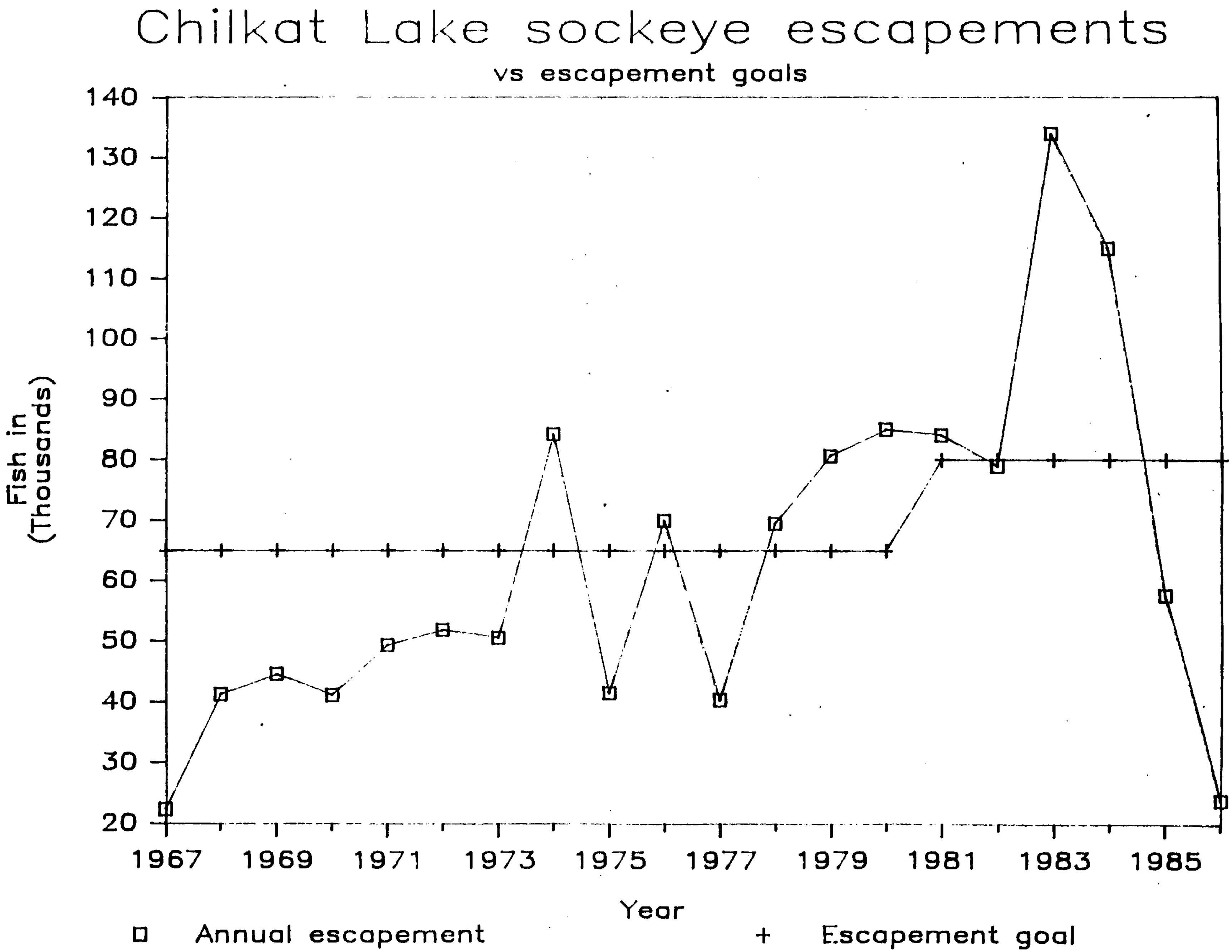


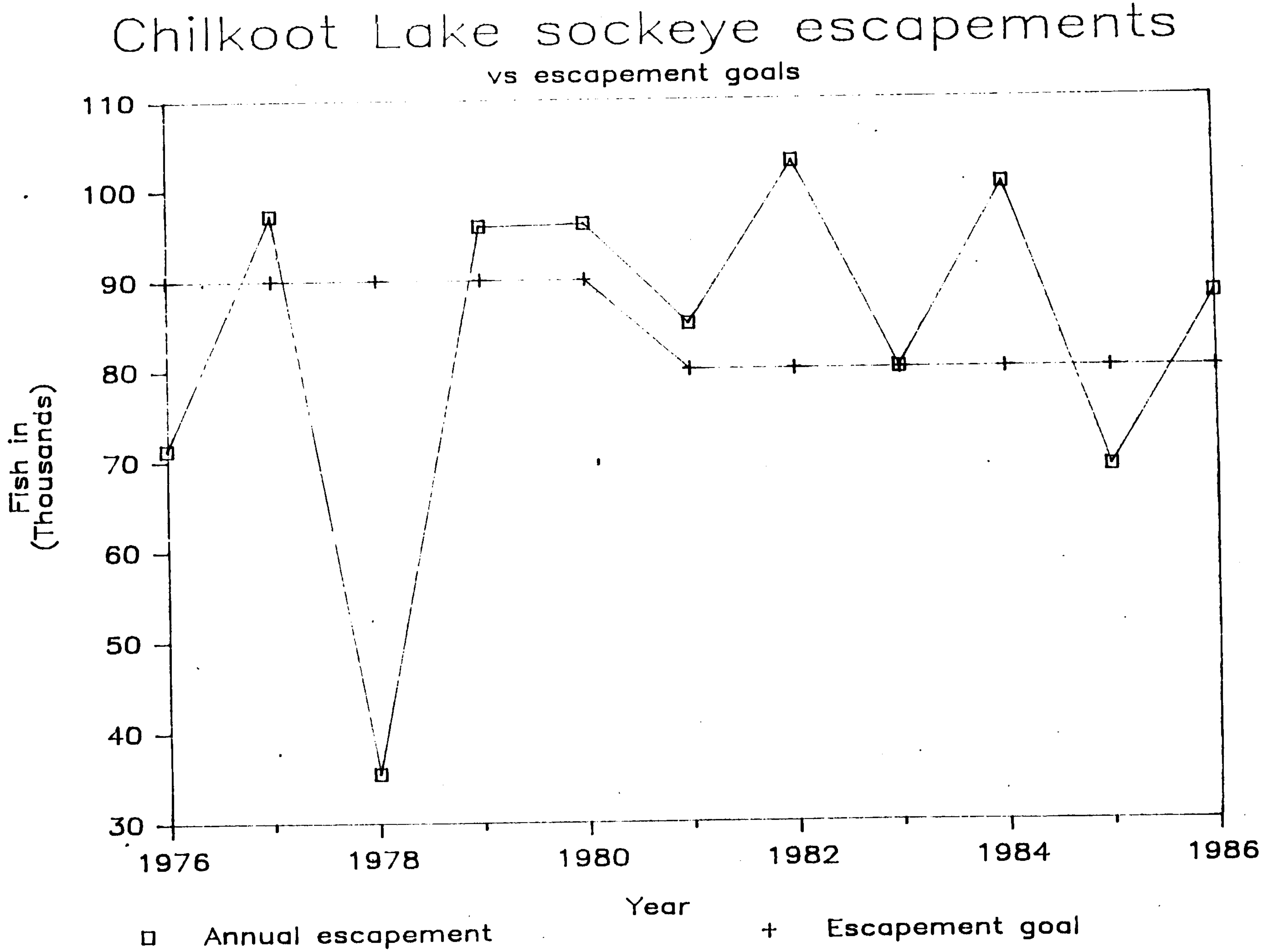
Figure 4. The Situk River and Yakutat salmon spawning systems.

Figure 5.



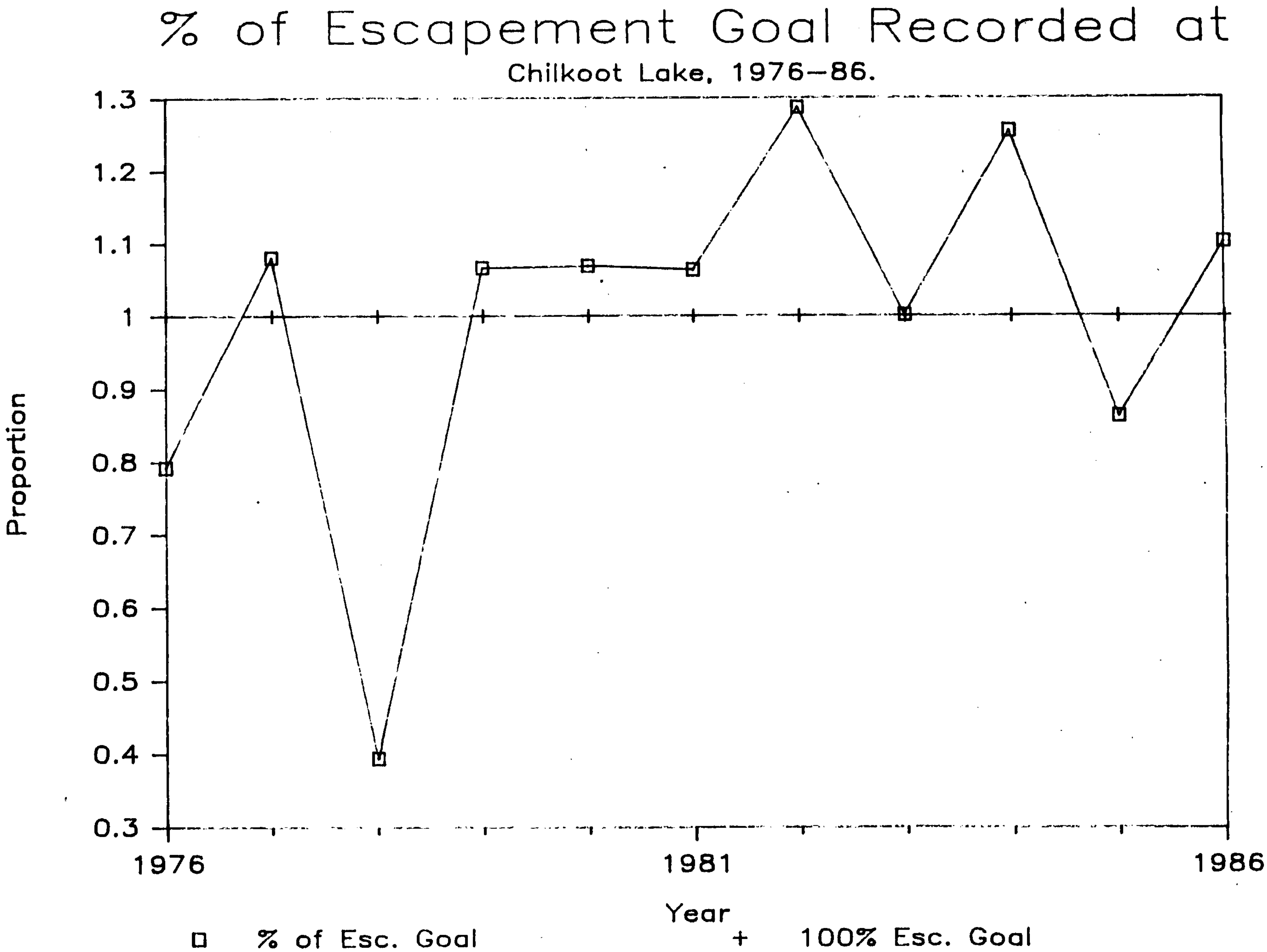
Chilkat Lake sockeye escapements
vs escapement goals
Fish in (Thousands)
140
130
120
110
100
90
80
70
60
50
40
30
20
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
Year
Annual escapement
Escapement goal

Figure 6.



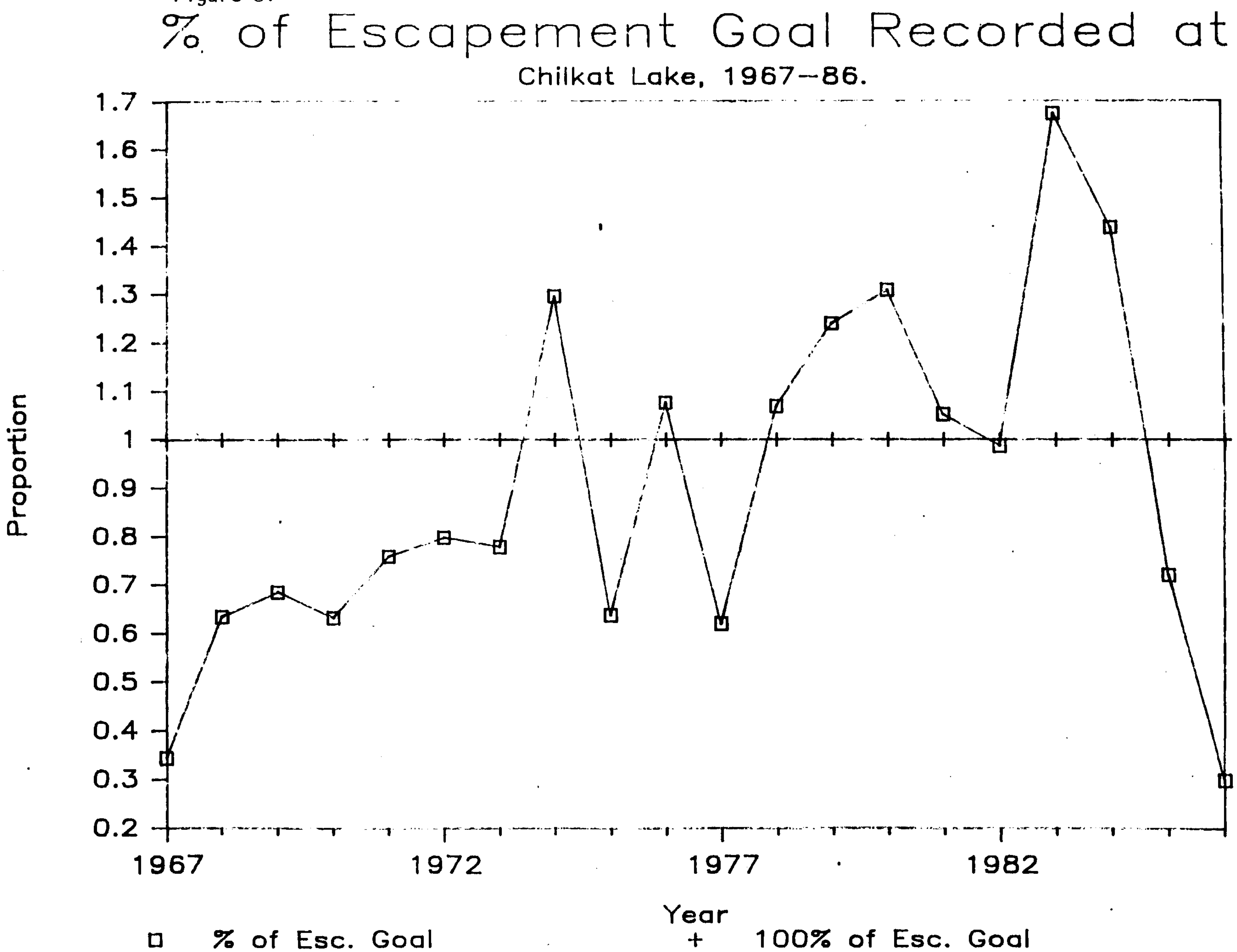
Chilkoot Lake sockeye escapements
vs escapement goals
110
100
90
80
70
60
50
40
30
Fish in (Thousands)
1976
1978
1980
1982
1984
1986
Year
Annual escapement
Escapement goal

Figure 7.



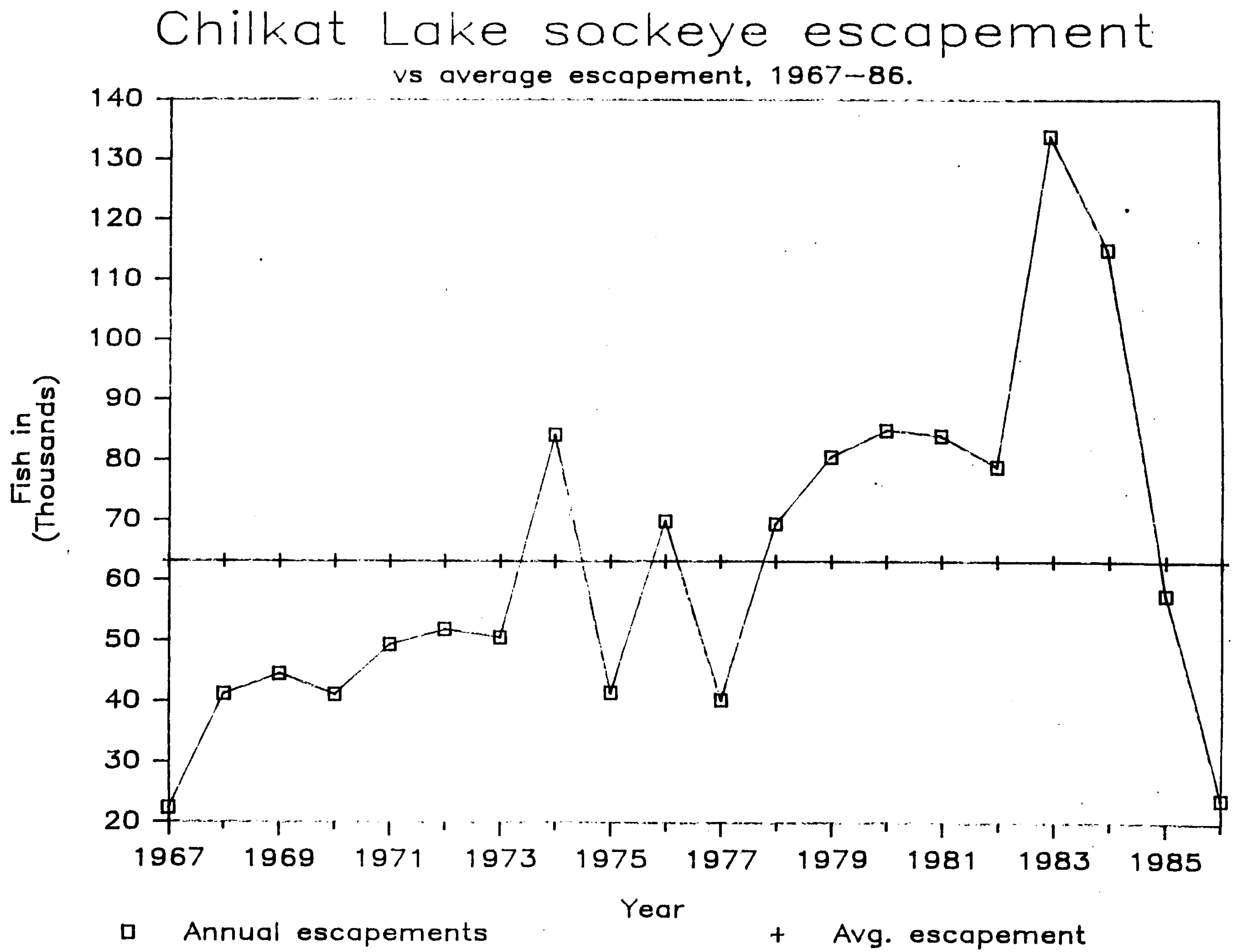
% of Escapement Goal Recorded at
Chilkoot Lake, 1976-86.
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Proportion
1976
1981
1986
Year
% of Esc. Goal
+ 100% Esc. Goal

Figure 8.



% of Escapement Goal Recorded at
Chilkat Lake, 1967–86.
Proportion
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
1967
1972
1977
1982
Year
□ % of Esc. Goal
+ 100% of Esc. Goal

Figure 9.



Chilkat Lake sockeye escapement
vs average escapement, 1967–86.
Fish in (Thousands)
140
130
120
110
100
90
80
70
60
50
40
30
20
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
Year
Annual escapements
+ Avg. escapement

Figure 10.

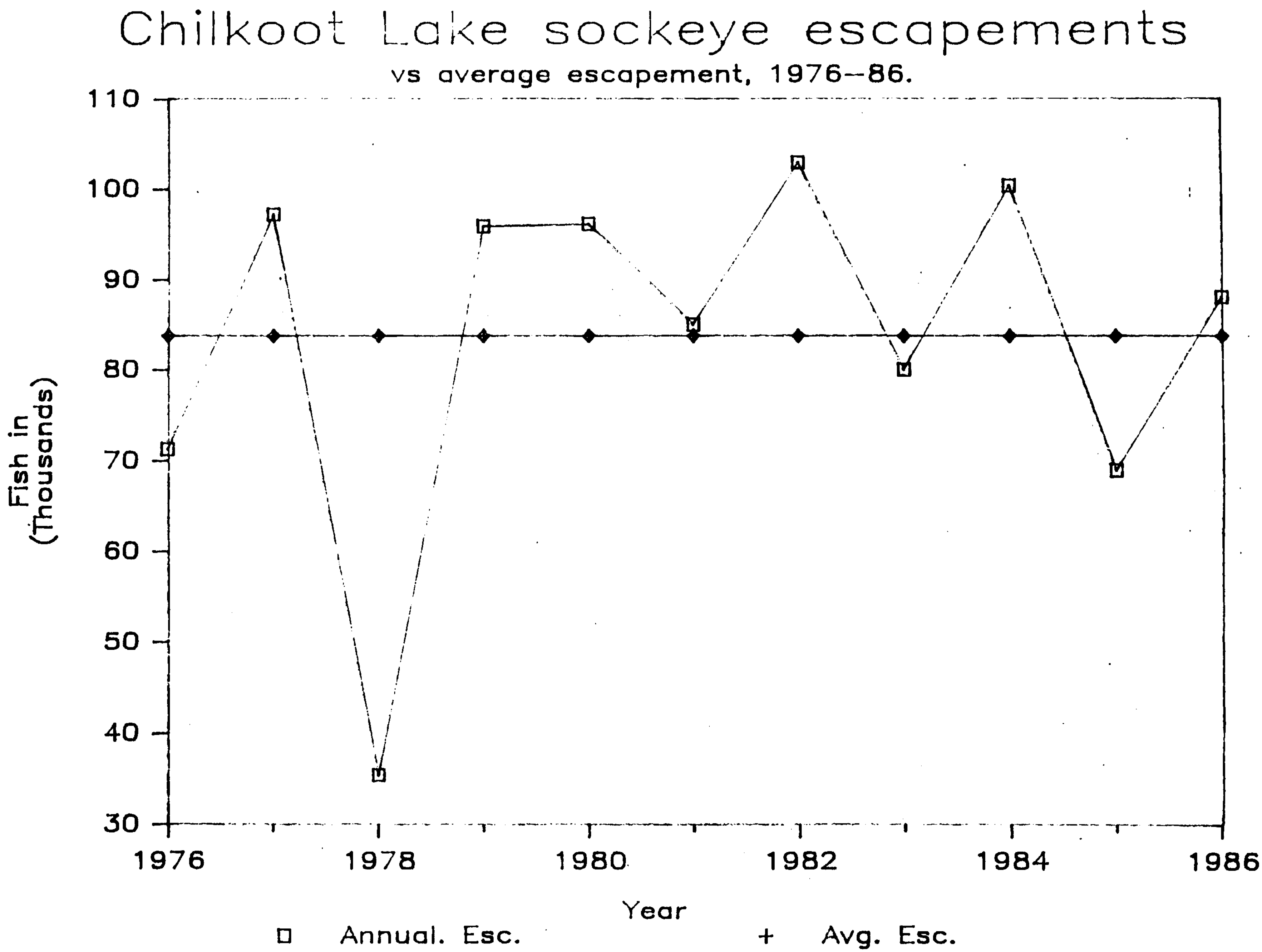

Chilkoot Lake sockeye escapements
vs average escapement, 1976–86.
110
100
90
80
70
60
50
40
30
Fish in (Thousands)
1976
1978
1980
1982
1984
1986
Year
Annual. Esc.
Avg. Esc.

Figure 11.

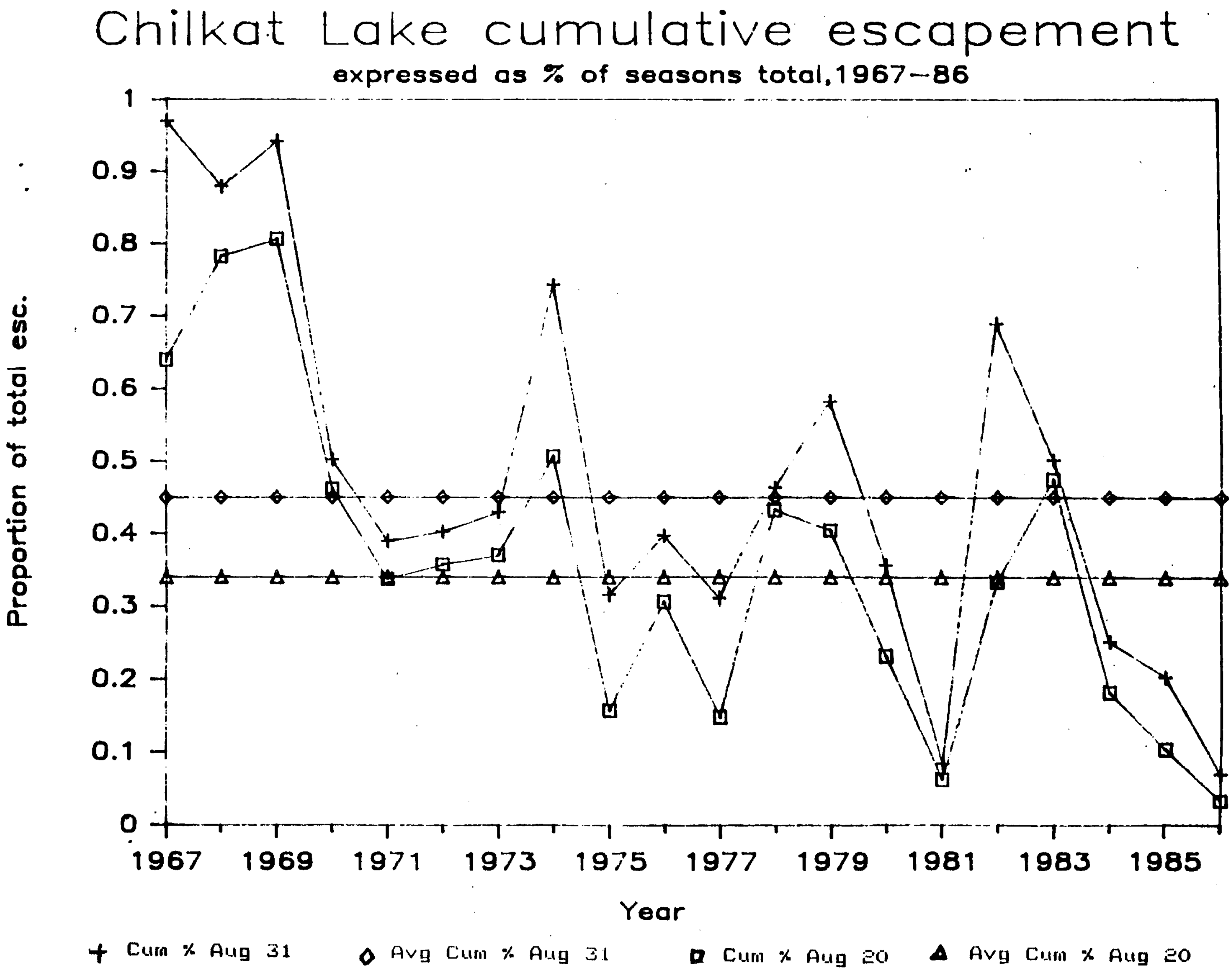

Chilkat Lake cumulative escapement
expressed as % of seasons total, 1967–86
Proportion of total esc.
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
Year
Cum % Aug 31
Avg Cum % Aug 31
Cum % Aug 20
Avg Cum % Aug 20

Table 1. Annual salmon escapements through Speel and Crescent Lakes Weirs, 1977-86.

Year	Sockeye	Coho	Pink	Chum	King	Total	Period Operated
Speel							
1983	10,362	43	143	0	0	10,548	7/01-9/22
1984	9,764	6	26	0	0	9,796	7/15-9/08
1985	7,073	0	0	2	0	7,075	7/15-8/29
1986	5,860	0	7	0	0	5,867	7/13-8/29
Crescent							
1977	1,079	10	3,449	115	5	4,658	7/07-8/29
1978	1,049	62	1,958	13	0	3,082	6/28-8/13
1983	19,476		no record		1	19,477	6/20-8/24
1984	6,807	33	6,047	685	4	13,576	7/10-9/12
1985	7,249	108	9,691	746	1	17,795	7/16-8/30
1986	3,405	28	1,046	228	4	4,711	7/12-8/29

Table 2. Southern Southeast Alaska sockeye salmon escapements, 1979-1986.

SOCKEYE SALMON ESCAPEMENTS a

YEAR	HUGH SMITH	McDONALD	KARTA	NAHA	SALMON BAY	KEGAN
1979	11,638 b	12,298 d	NE	NE	NE	NE
1980	12,714	63,936 d	NE	NE	NE	NE
1981	15,445	129,653	NE	NE	NE	NE
1982	57,224	34,080 e	41,492	NE	16,041	14,385
1983	10,427	56,142	22,454	4,580	14,023	8,651
1984	16,191	121,224	NE	NE	5,668	NE
1985	12,233	133,000 f	31,564	NE	34,308	NE
1986	2,312 c	100,000 f	5,929	10,612	9,095	NE

a All counts not otherwise specified were weir counts.

b Total of foot surveys

c Weir was not fish tight. A Peterson estimate from fish tagged at the weir produced a point estimate escapement of 6,968 sockeye.

d These escapements were the result of foot surveys and were later revised by back calculating using correction factors resulting from a comparison of weir counts with Peterson estimates for the years 1981,1983 and 1984. The revisions produced escapement estimates of 25,000 and 80,000 for 1979 and 1980, respectively.

e The weir washed out after 34,080 fish had been counted. A Peterson estimate indicated that approximately 50,000 fish had escaped to th lake.

f These escapements were the result of Peterson estimates and stream surveys.

To: Dave Cantillon
Regional Supervisor
Commercial Fisheries Division
Douglas

Date: January 9, 1987

From: Fred Bergander
Fisheries Biologist
Commercial Fisheries Division
Douglas

Subject: Escapement Goals

Re: our earlier conversation about establishing escapement goals for Southern Southeastern Alaska Sockeye systems. Following is a summary of escapement goals for select sockeye systems in Southern Southeastern that I recieved from Don House. The escapement goals were formulated using two approaches; 1) basing the escapement goals on 25-50 spawners per surface acre, the spawning density observed at systems such as Chilkoot and Chilkat, 2) basing the number of spawners on the estimated level of primary productivity of the lakes as determined by the FRED Division.

Lake	Surface acres	Escapement goal based on 25/50 spawners/acre in thousands	Escapement goal based on primary productivity in thousands
Klawock	2906	72.6-145.3	232.5-290.6
Hetta	518	13.0-25.9	41.4-51.8
Karta			
(Both lakes)	1465	36.6-73.3	117.2-146.5
Kegan	605	15.1-30.3	48.4-60.5
McDonald	1035	25.9-51.8	82.8-103.5
Hugh Smith	800	20.0-40.0	64.0-80.0
Helm Lake	205	5.1-10.3	16.4-20.5
Bakewell	690	17.3-34.5	55.2-69.0
Badger	538	13.5-26.9	43.0-53.8

U.S./Canada Research Salmon Interception Studies,
southern Southeast Alaska
and northern British Columbia
1982 and 1983

Steve Hoffman
Commercial Fisheries Division
Alaska Department of Fish and Game

A major adult sockeye salmon tagging project was conducted during 1982 and 1983 in southern Southeast Alaska and northern British Columbia. The objectives were to investigate the interception rates of sockeye salmon in selected fisheries, and to identify migration patterns, run timing, and degree of stock intermingling for sockeye returning to these areas. Previous sockeye salmon tagging investigations had illustrated the extremely mixed nature of southern Southeast Alaska and northern British Columbia sockeye salmon fisheries, defined major stock groups, and identified major migration routes. However, additional information on sockeye salmon interception rates in boundary area fisheries, coupled with more precise information on sockeye salmon migration pattern, run timing, and stock intermingling, is required for effective salmon management by both country's fisheries management agencies.

A total of 8,720 and 9,998 sockeye salmon were tagged and released in 1982 and 1983, respectively, during operation of the project in southern Southeast Alaska. In addition, 36,875 and 23,716 sockeye salmon were tagged and released in 1982 and 1983, respectively, by the Canadian Department of Fisheries and Oceans in northern British Columbia (Fig. 1). Chartered seine, gillnet, and troll vessels (Canadian only) were employed to capture sockeye salmon in a number of general coastal water release areas in southern Southeast Alaska and northern British Columbia (Figures 2 and 3). In addition, secondary tagging was conducted in the Stikine (1983 only), Nass, and Skeena Rivers (1982 and 1983). Highly visible, sequentially numbered, and uniformly labeled red Peterson disk tags were used to facilitate maximum commercial and spawning stream recoveries. During 1982 35.6% of the sockeye salmon released (4.9% in Alaska, 30.7% in Canada) were recovered, while in 1983 20.7% (4.1% in Alaska, 16.6% in Canada) were returned (Figure 4). Tag recoveries during both years were reported from spawning streams, commercial fisheries, sport fisheries, and incidental public returns, with the majority of tags recovered in-stream and during commercial fisheries.

The distribution of recovered sockeye salmon tags released in 1982 and 1983 in southern Southeast Alaska illustrated that District 101 and 102 sockeye salmon return via Dixon Entrance and Sumner/Clarence Strait, while District 103 and 104 sockeye salmon move directly inshore via numerous west coast island passages and Cordova Bay. The majority of District 106, and 107 sockeye salmon stocks move inshore to their natural streams via lower Sumner Strait while a small percentage return via Dixon Entrance and lower Clarence Strait (Figures 5-7). Sockeye salmon destined for northern British Columbia systems return via several different routes. Skeena River sockeye return via Dixon Entrance, Sumner/Clarence Strait, and lower

Hecate Strait, while Nass River sockeye move inshore to their natural stream via Dixon Entrance and Sumner/Clarence Strait (Figures 8 and 9).

Sockeye salmon inshore migrations occurred in a fairly orderly manner throughout the study areas. Peak migration periods were evident for some individual stocks and larger units, suggesting that effective management strategies based on run timing may be devised by adjusting fishing periods to, or around, migration periods and/or homogeneous areas to protect or direct harvest to selected stocks. However, this approach may be limited by the degree of stock intermingling in most areas of southern Southeast Alaska and northern British Columbia, especially during June and July.

Interception rate estimates in the primary tag release areas were derived from the 1982 (Alaskan and Canadian analysis) and 1983 (Canadian analysis only) adult salmon tagging studies. These estimates would be expected to reflect national stock portions in the study areas during the tag release periods for the combination of relative stock size and migration patterns which occurred during these two years. Estimates of 1982 Canadian contribution rates in eight southern Southeast Alaska study areas ranged from 21 to 80 percent for sockeye, with Noyes/Dall Island reporting the highest rates (Table 1). In seven northern British Columbia study areas, estimated Alaskan contribution rates ranged from 0 to 11 percent, with Area 1 seine reporting the highest rate (Table 1). Results of the 1983 tagging study indicate Canadian contribution rates in six southern Southeast Alaska study areas ranged from 31 to 95% for sockeye, with Dall Island reporting the highest rate (Table 1). Interception rates for six Canadian study areas for Alaskan stocks ranged from 0 to 4 percent for sockeye, with Area 1 seine reporting the highest rate (Table 1.)

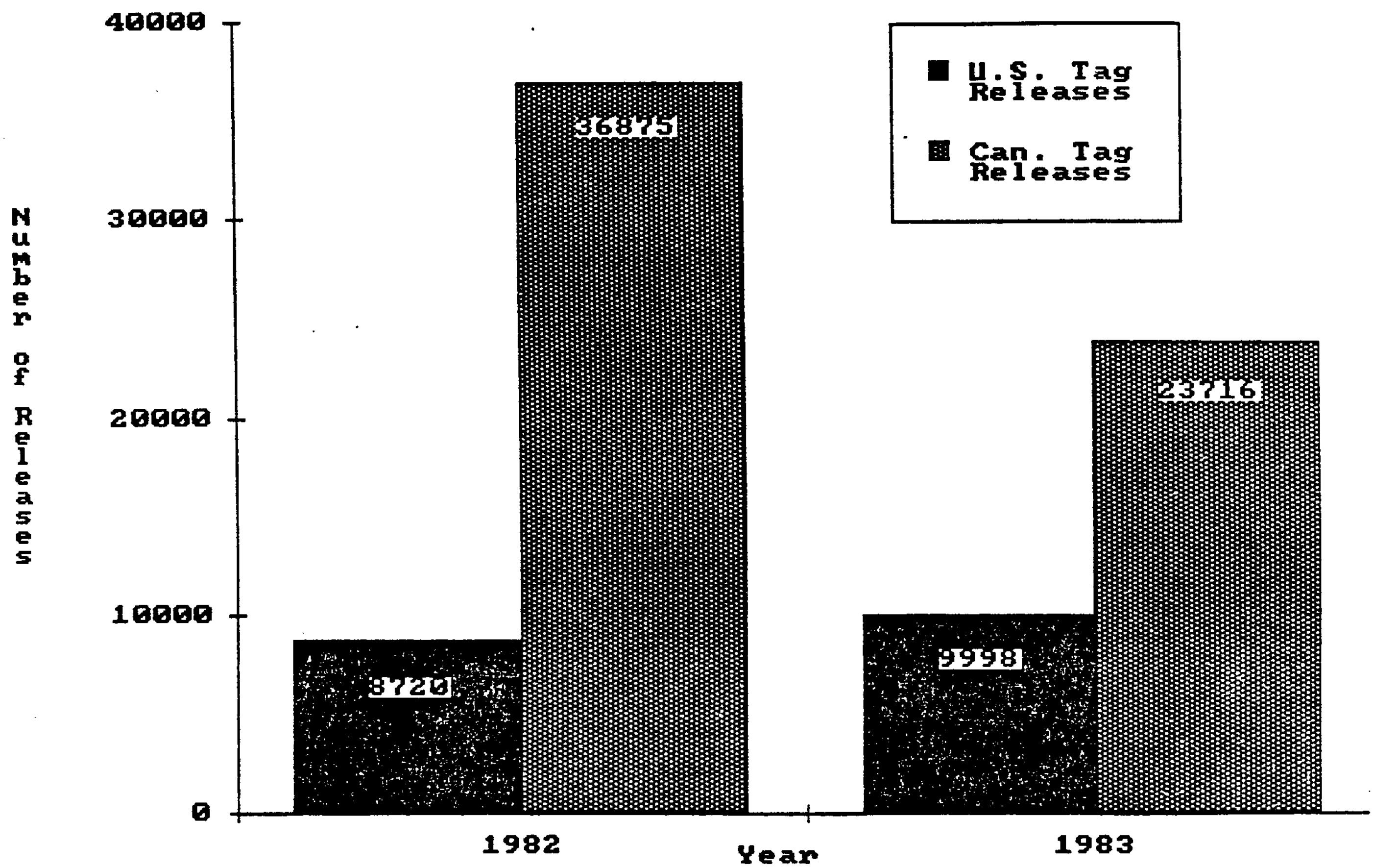


Figure 1. U.S./Canada sockeye salmon Peterson disk tag releases, 1982 and 1983.

Tagging and Recovery Locations, 1982

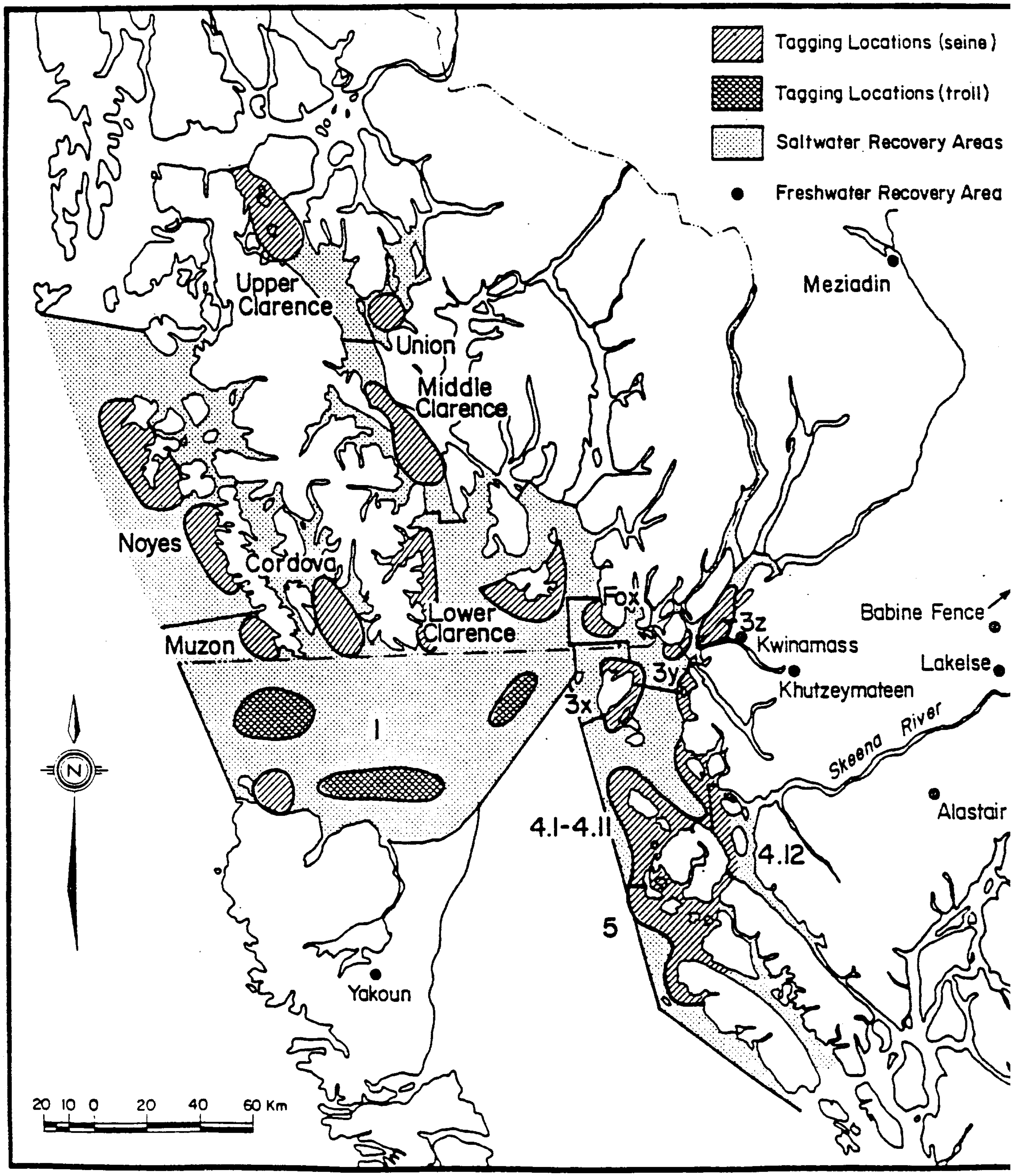


Figure 2. U.S./Canada interception research sockeye salmon tagging and tag recovery locations, 1982.

Tagging and Recovery Locations, 1983

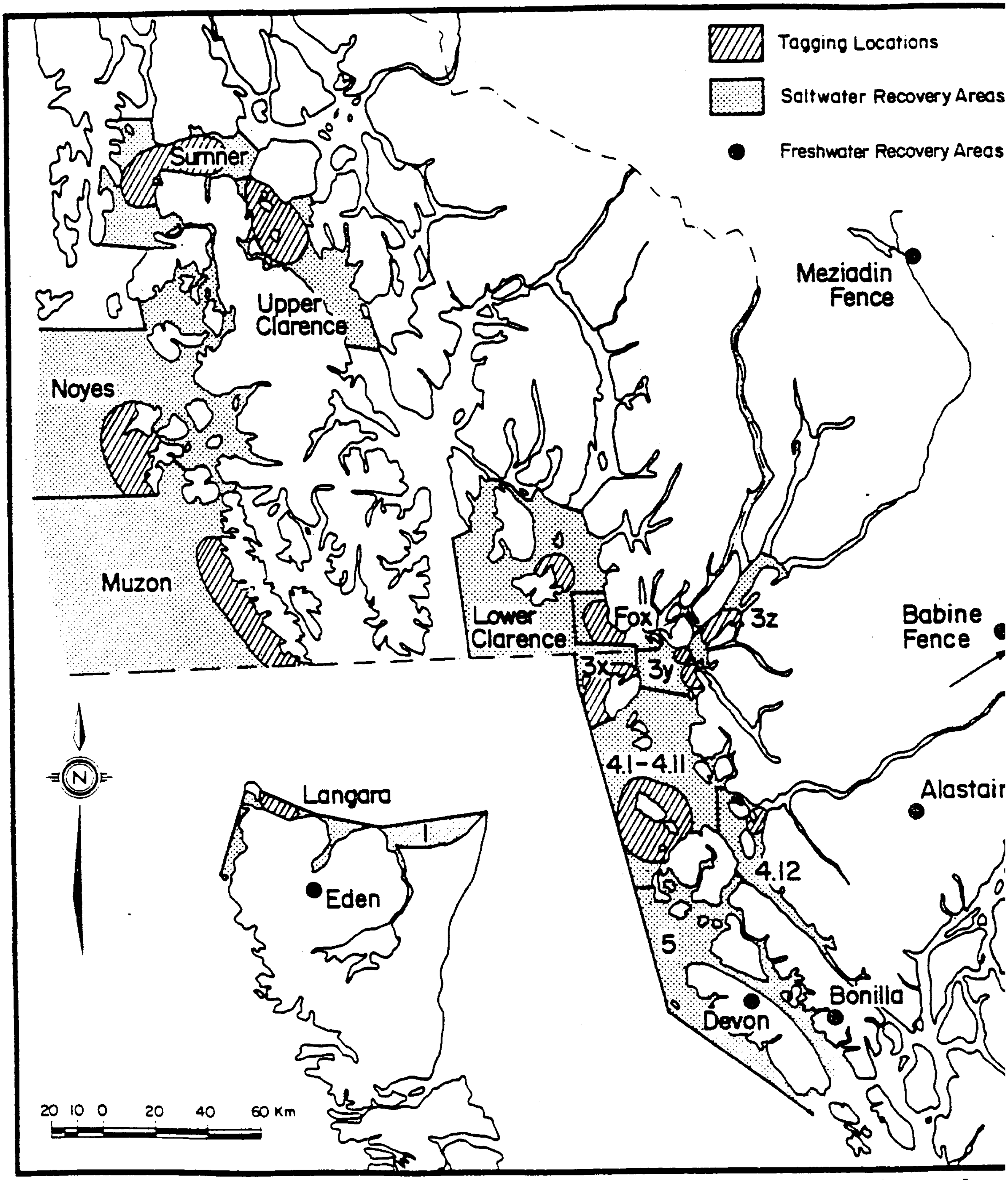


Figure 3. U.S./Canada interception research sockeye salmon tagging and ta
recovery locations, 1983.

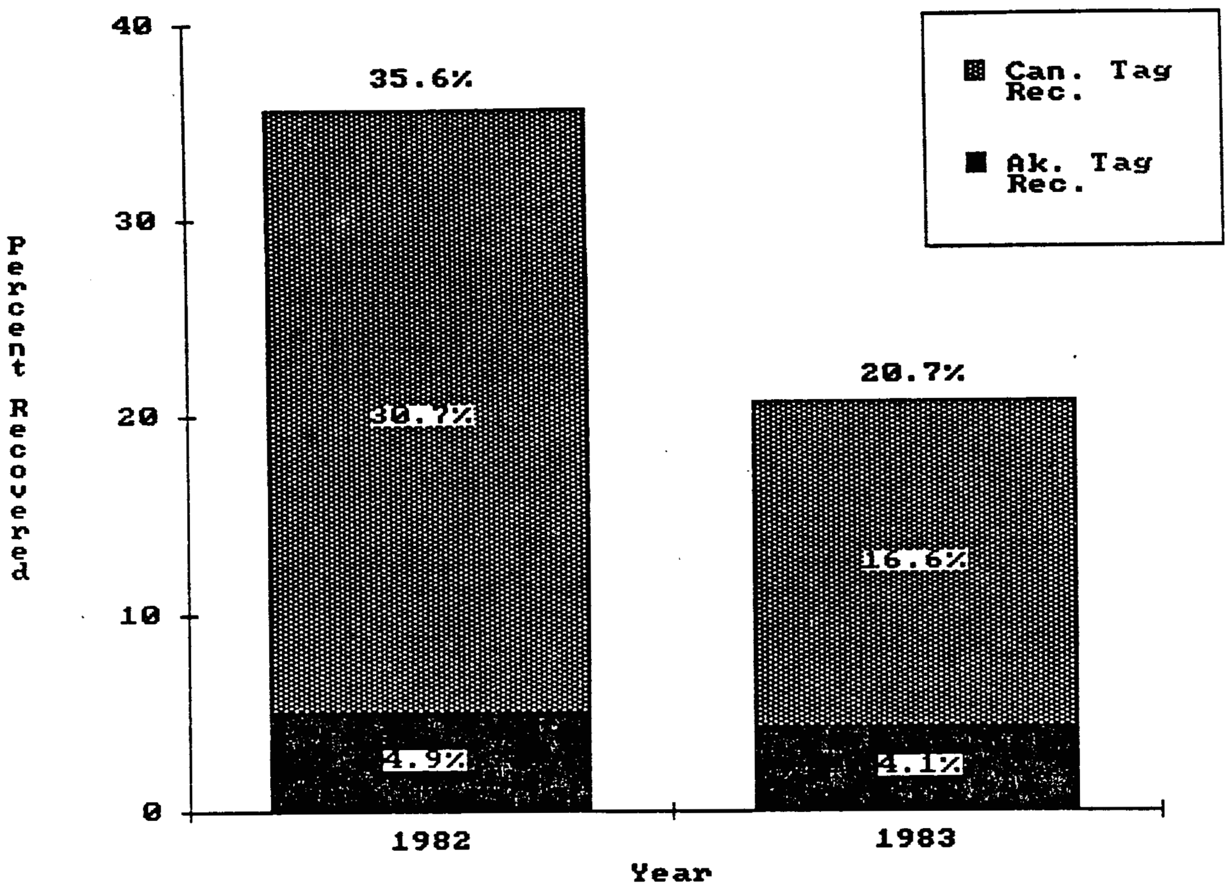


Figure 4. U.S./Canada research sockeye salmon tag recoveries, 1982 and 1983.

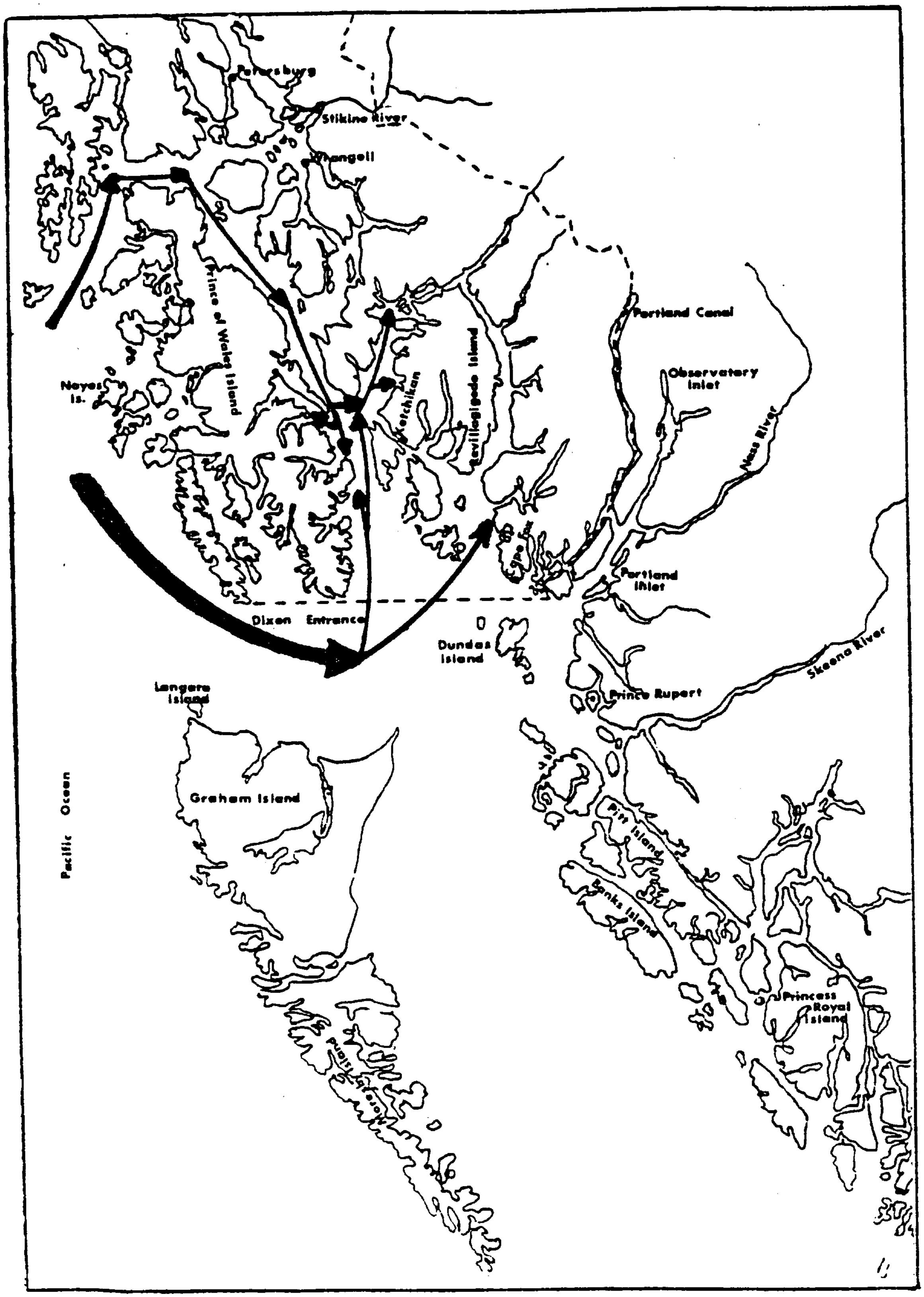


Figure 5. Alaskan Districts 101 and 102 sockeye salmon migration routes, 1982 and 1983.

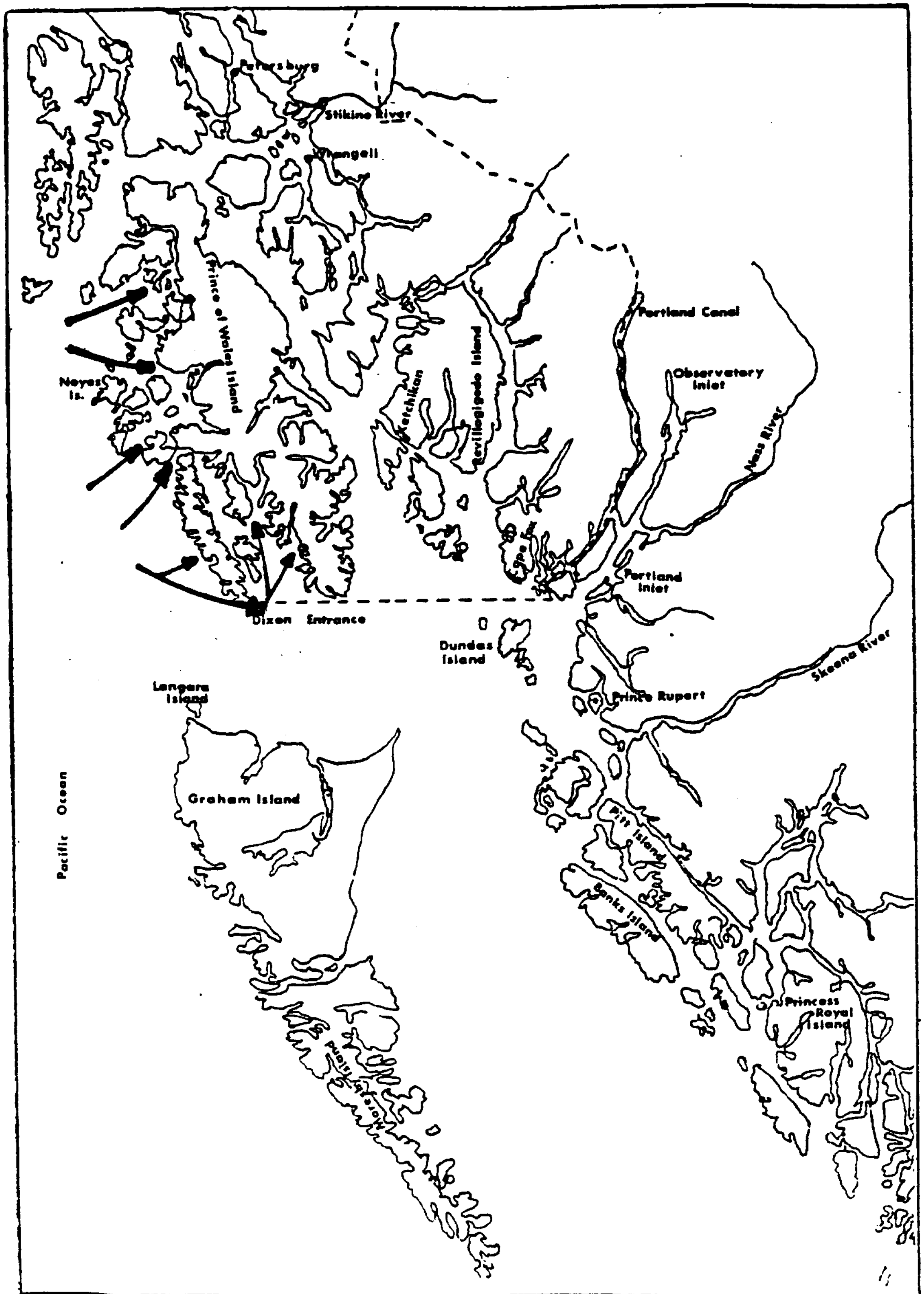


Figure 6. Alaskan Districts 103 and 104 sockeye salmon migration routes, 1982 and 1983.

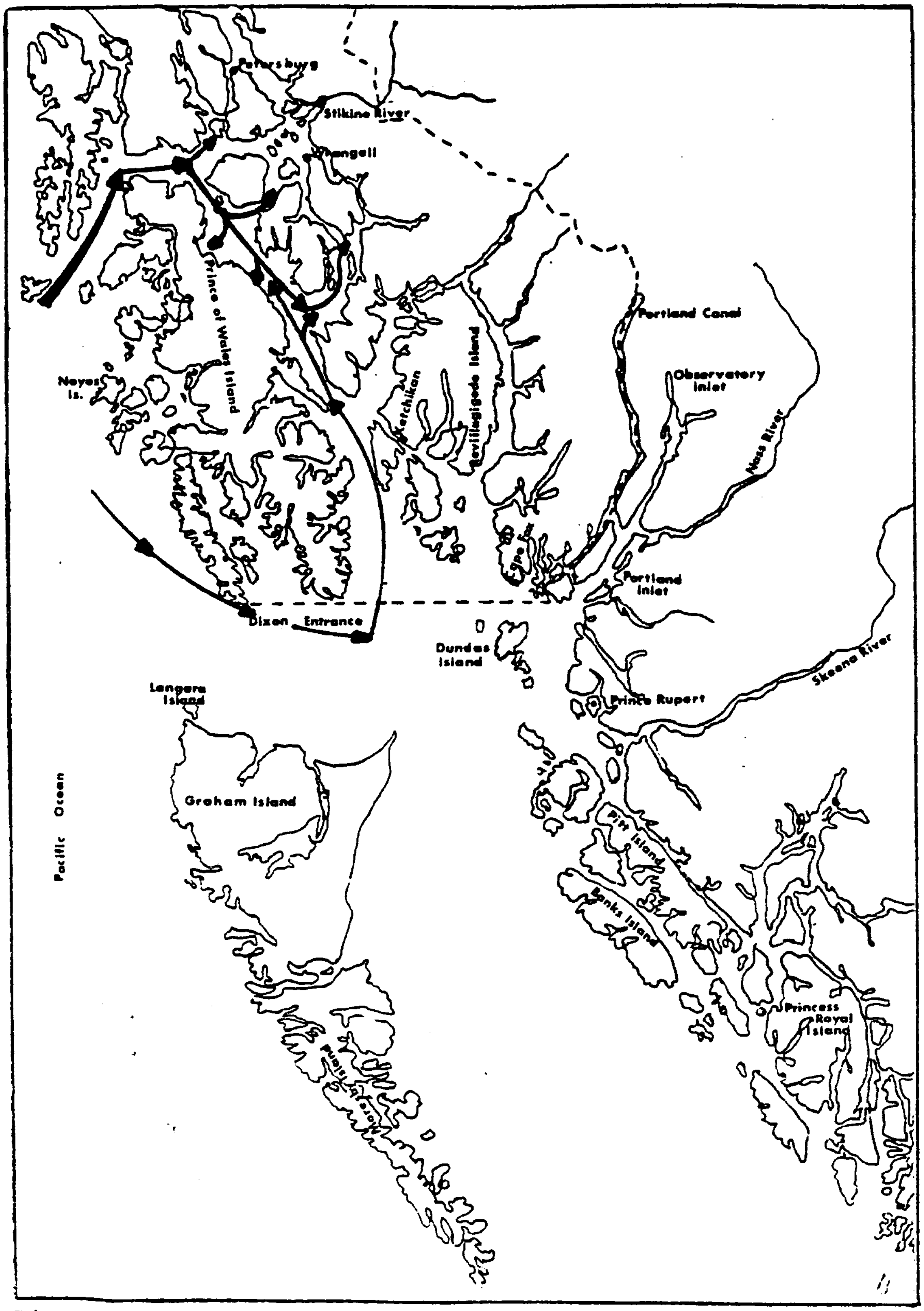


Figure 7. Alaskan Districts 106 and 107 sockeye salmon migration routes, 1982 and 1983.

Migration Routes, Skeena Sockeye 1982 and 1983

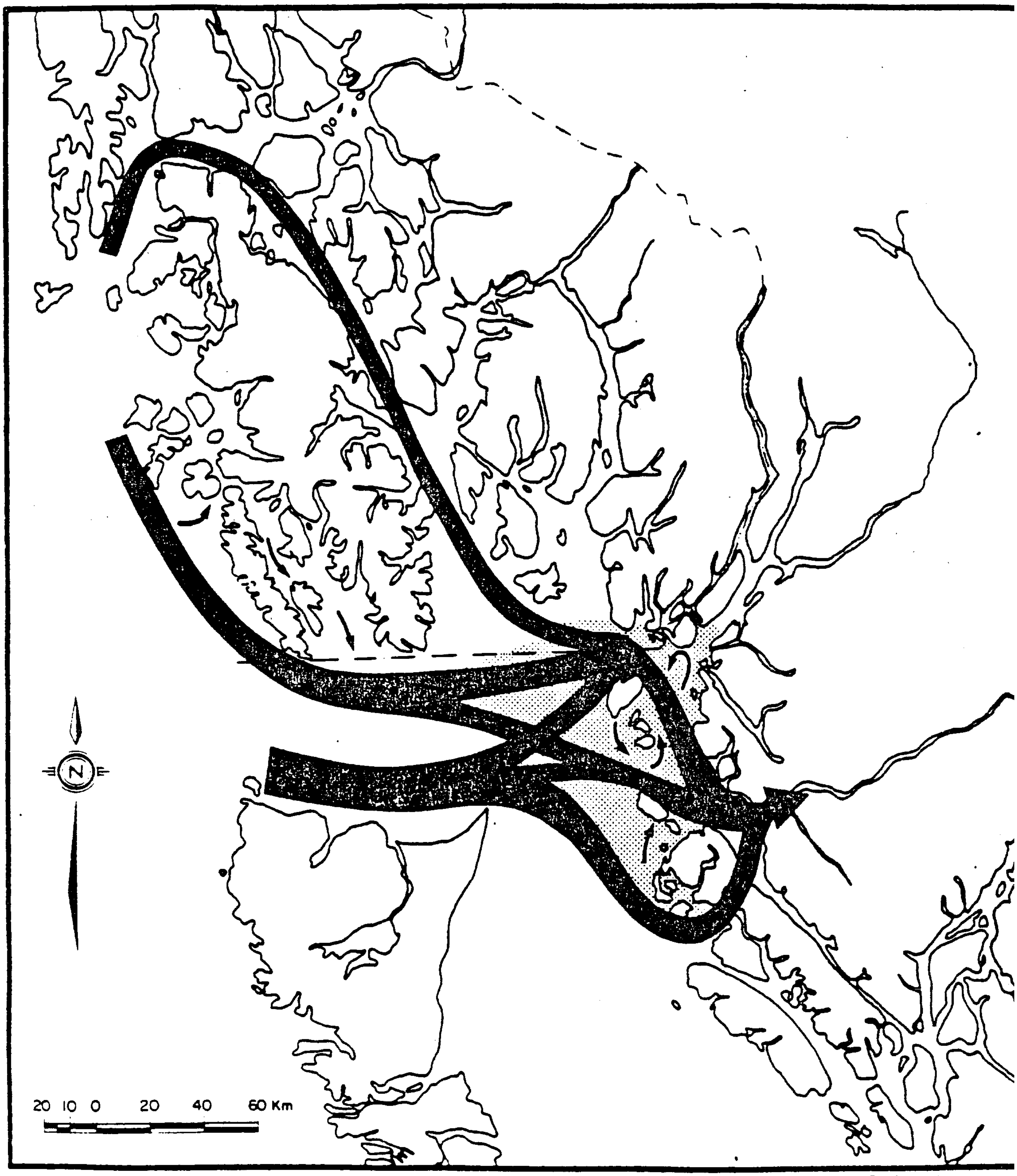


Figure 8. Skeena River sockeye salmon migration routes, 1982 and 1983.

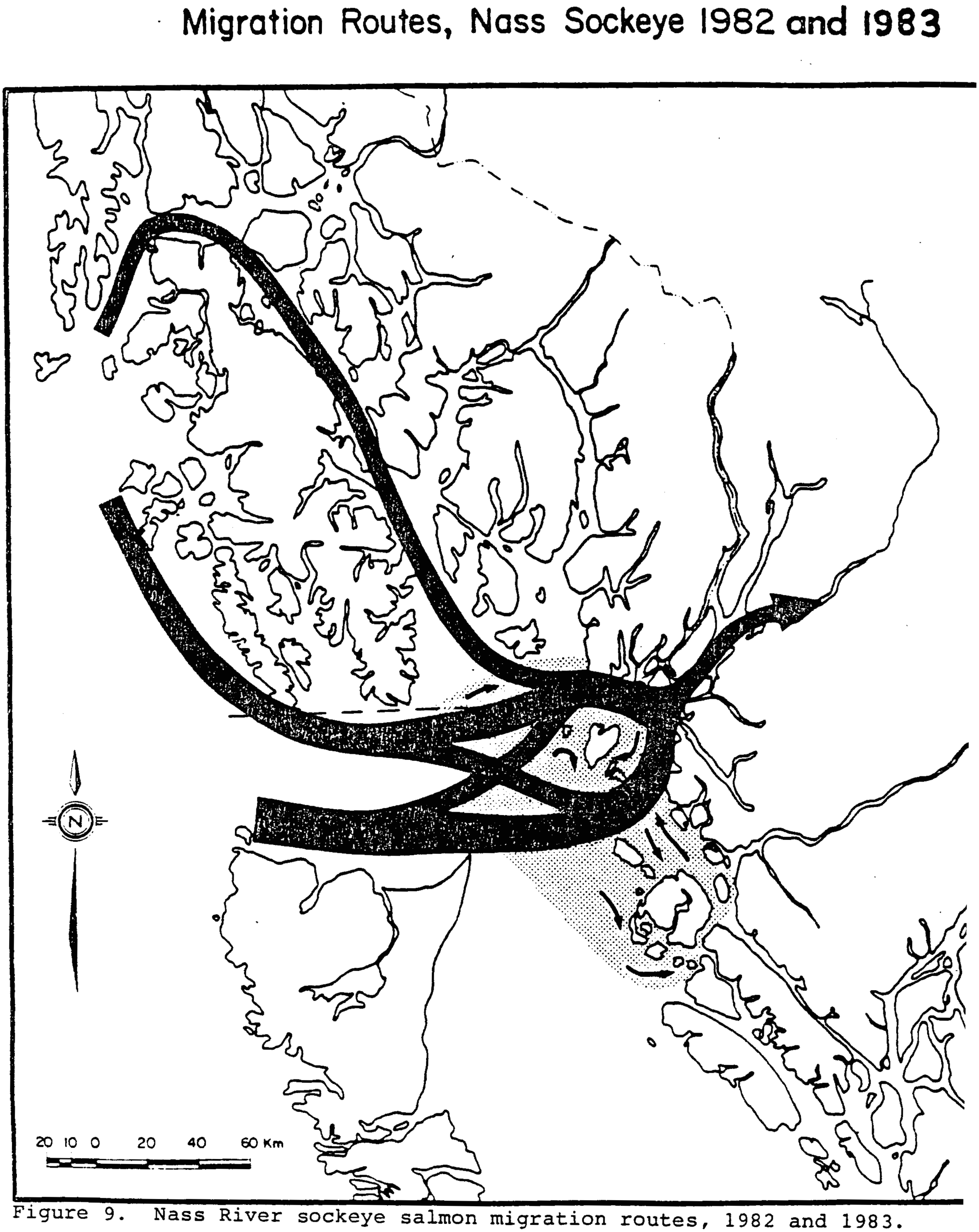


Figure 9. Nass River sockeye salmon migration routes, 1982 and 1983.

Table 1. U.S./Canada sockeye salmon interception rates for southern Southeast Alaska and northern British Columbia Fishery Areas, 1982-1983.

Area	1982* U.S. (Percent)	1982* Canada (Percent)	1983** U.S. (Percent)	1983** Canada (Percent)
Area 1 Troll	0	100	-	-
Area 1 Seine	11	89	4	96
Area 3X	5	95	1	99
Area 3Y	5	95	2	98
Area 3Z	5	95	0.5	99.5
Area 4	8	92	0.5	99.5
Area 5	1	99	0	100
Noyes Island	21	79	9	91
Muzon/Dall Island	20	80	5	95
Summner Strait	-	-	69	31
Upper Clarence	31	69	55	45
Middle Clarence	57	43	-	-
Lower Clarence	79	21	6	94
Cape Fox	29	71	10	90
Cordova Bay	65	35	-	-

* U.S. and Canadian analysis
** Canadian analysis only

OVERVIEW OF SCALE PATTERN ANALYSIS

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INTRODUCTION

Scale pattern analysis (SPA) is an important management tool used in fisheries throughout Alaska. Scale pattern analysis is used to make estimates of the stock composition of fish harvested in mixed stock fisheries, ie. what are the proportions and number of each of the major stocks that contribute to a fishery. Obviously the management of mixed stock fisheries, which most Alaskan fisheries are, would be enhanced if reliable estimates were available of the weekly harvest by stock.

Results of a SPA are used in-season mainly to evaluate run strength, run timing, and the spatial distribution of each stock. This information is needed by the managers to selectively harvest or protect certain stocks and regulate harvest rates so that escapement goals are met. Post-season, SPA estimates of the number harvested by stock is used to evaluate success of management strategies, in migratory timing studies, and in run reconstruction needed for spawner-recruit models for forecasting returns and setting escapement goals.

Scale pattern analysis is also useful in allocating catches between user groups, and nations as is the case between U.S. and Canada where annual estimates of interceptions are needed to determine entitlements as defined in the Pacific Salmon Treaty. As a consequence, results from a single SPA are often used to meet the goals of both conservation and allocation.

In this paper I review the overall methods for doing SPA and describing the applications of SPA in the management of Southeast Alaska's sockeye salmon fisheries. I will also discuss the development of "mixture models" in which two or more biological markers, age composition, SPA, brain parasite, or genetic stock identification (GSI), are combined in a single stock identification model. The discussion will center primarily on the application of SPA rather than on details of results from these studies.

OVERVIEW OF SCALE PATTERN ANALYSIS

The pattern of circuli on scales is a history of the growth of the fish. Salmon with similar growth histories have similar patterns of circuli, while those with different growth histories have different patterns. Scale pattern analysis (SPA) then employees this natural "biological marker" using pattern recognition methodology to assign a fish sampled from a mixed stock fishery to the group which its scale pattern most represents.

To do a SPA, scale data from fish of known origin are combined in a multivariate discriminant model which maximizes between group differences relative to within group differences. This model is then used to classify fish of unknown origin, from the catches, into one of the groups in the model.

To accurately classify fish, one first needs to determine what runs/stocks contribute to the fishery and how these runs should be grouped (if necessary). The grouping of stocks are based both on the needs of management and differences in scale patterns.

The accuracy of a SPA model depends on differences in growth histories between stocks, and when historical models are used, on presence of consistent and persistent differences between years. The precision of an allocation made through SPA is dependent upon: (1) the model accuracy; (2) the size of the sample used to construct and evaluate the rule; (3) the size of the sample drawn from the stocks when mixed; and, (4) when the analysis is stratified by age class, the precision of the age composition estimates.

There are a number of pattern recognition methods - linear discriminant function (LDF), quadratic discriminant function, polynimial discriminant function, nearest neighbor, maximum likelihood, and others. Each method requires different assumptions about the underlying distributions of the variables, with LDF being the most restrictive, requiring that variables by normally distributed among other things. In actuality, LDF has been found to be fairly robust against deviations from normality with large sample sizes and continuous variables and we typically use it.

Compared to other stock identification techniques, SPA has several distinct advantages: scale data is usually already available since baseline age, sex, and size data is routinely sampled from all major catches and escapements; scales are easy to store and do not deteriorate with time; replicate copies of scale impressions are easy and inexpensive to make, facilitating independent confirmation of results; the accuracy and precision of classification rules is easily tested; and acquisition of scale pattern data is rapid and analysis is simple, thus cost is low.

Limitations for SPA include: all major contributing stocks must be present in the model; there must be measurable differences in scale patterns between groups; models can be very sensitive to the way the standards are constructed (especially if within-group variability is large), and underlying assumptions must be met for the model chosen. Results from tagging studies are helpful in determining what stocks contribute to a fishery and sensitivity analysis, employing results from tagging studies among other things, are helpful for evaluating and controlling bias in model construction.

All SPA conducted by Stock Biology Group personnel is done in a manner which controls several known or potential sources of variability. All SPA models are age class specific; age pooled models have generally failed to yield results equivalent to age-specific models. In-season classifications are based on historical models which are updated annually or, in some cases, with current year standards. Post-season classifications are based on current year standards. All in-season classifications are re-run post-season to calculate the best possible estimates despite in-season estimates seldom falling outside the 90% confidence bounds of the post-season estimates. The same reader digitizes all scales used in an analysis.

The accuracy of the Linear Discriminant Function (LDF) models are tested using a leaving-one-out "jackknife" procedures. The accuracy of the models is further enhanced using an adjustment matrix based on the error rate from the leaving-one-out procedure. Variables are added to the model using a stepwise selection procedure (see Marshall et. al. 1984).

All scale analysis for this Region is currently done in our "Scale Lab" at the regional office in Douglas. Accetate impressions of scales are projected at 100X magnification onto a digitizing tablet on which a trained reader electronically points out the location of each circuli within predefined scale zones along a linear axis of the scale perpendicular to the anterior-posterior fields (Figure 1). Our custom, microcomputer based, software then generates variables based on the number and spacing of circuli in each of the scale zones. Custom FORTRAN programs are used to construct LDF models and classify catch samples. The accuracy and precision of all classifications is routinely computed and reported.

The Department is developing an automatic optical pattern recognition system. This system shows great potential for improving the efficiency, controlling the reader variability, and, possibly, increasing the accuracy of SPA based catch allocations. Within a few years aging and determinations of stock origins might be accomplished by simply putting a stack of accetates in the hopper of a machine which automatically determines (estimates) the age and stock of origin of each scale.

APPLICATIONS OF SPA IN SOUTHEAST ALASKA

The Division of Commercial Fisheries currently employs SPA in the in- and post-season management of over 10 Alaskan fisheries. In Southeast Alaska SPA is used in the in-season management of sockeye salmon in the Lynn Canal gillnet fishery (McPherson 1987), the Taku/Snettisham gillnet fishery (McGregor 1896), and the Prince of Wales (District 106) and Stikine (District 108) gillnet fisheries (Oliver and McGregor 1986). Scale pattern analysis is used post-season to allocate sockeye salmon catches in all Boundary and Transboundary area gillnet and seine fisheries in the region (Oliver and Jensen 1986). Scale pattern analysis is also used to evaluate run timing and run strength of the various stocks in the Stikine and Taku Rivers. We also have conducted SPA in-season to estimate the stock composition of sockeye salmon harvested in District 101 seine and gillnet fisheries. Scale pattern analysis was used by the Department, along with migratory timing information and tagging, to prove that the Kayak Island purse seine fishery intercepted sockeye bound for systems outside the Cordova area.

Lynn Canal - A Classical Application of SPA

Scale patterns of the two main contributing stocks, Chilkat and Chilkoot (Figure 2), are so unique, that a trained scale reader (ie. Scott McPherson the Project Biologist) can correctly identify stock origins better than 93% of the time based solely on visual examination of scales on a microfiche reader. The fish grow slower in the colder, glacially occluded Chilkoot Lake than in the warmer, more eutrophic Chilkat Lake. This difference in growth environments is reflected in the scales, with Chilkoot fish having substantially fewer freshwater circuli and smaller freshwater zones than Chilkat fish.

Our Stock Biology Group has estimated weekly stock compositions of the Lynn Canal fishery catch since 1981. Our estimates were originally based on multivariate discriminant function analysis of digitized scale data, however the past three years Mr. McPherson has estimated stock compositions based solely on visual differences. The accuracy of his visual classifications is tested annually via. a "blind test".

Mr. McPherson currently assigns catch samples into one of three groups - Chilkat, Chilkoot, and Other. The Other group consists of Chilkat mainstem and Berners River stocks and significant contributions occur only during the first few weeks of the season. Mr. McPherson also estimates the contribution of Lynn Canal fish to the District 112 purse seine fishery.

In-season SPA involves project personnel sampling commercial landings in Excursion Inlet and other ports of landing and immediately forwarding this scale data to Juneau where Scott McPherson ages and stock ID's each fish. Scott then provides the management biologists within just a few hours of receipt of the scales with an estimate of the proportion harvested by stock. These stock composition estimates when combined with the weekly catch data yields an estimate of the harvest by stock. These estimates are then used in the management models mentioned above.

The results of these weekly SPA's is an integral part of in-season management models (there's more than one) that combine stock composition estimates from SPA with catch, escapement, CPUE, age composition, and migratory timing data to: (1) forecast returns; and (2) estimate escapements (particularly of Chilkat fish).

Results of SPA are useful in understanding the spatial distribution of the stocks and assets the manager in directing the harvest to selectively harvest or protect certain runs.

The big problem facing management of Lynn Canal sockeye salmon now is to consistently attain, but not exceed, escapement goals for the Chilkat Lake run. Escapements for this run have ranged between -69% and +68% of the desired escapement the since 1981. Such large deviations have not occurred for Chilkoot Lake escapements, largely because escapements are known after only a five day lag from the fishery compared to a 2 to 4 week lag for Chilkat.

Current research centers on: (1) employing stock specific historical migratory timing data to predict future returns; and (2) use of stock specific catch-per-unit-of-effort data to predict Chilkat escapement.

The Lynn Canal fishery data base is certainly one of the best in the world with a long time series of accurate catch and escapement estimates and, since 1981, estimates of the harvest abundance, age, sex, and size composition, by stock.

Taku/Snettisham Gillnet Fishery - SPA Evolves

Under Andrew McGregor's reins, SPA based estimation of the stock composition of District 111 sockeye salmon gillnet catches has undergone quite an evolution. Initial stock identification work, 1981 to 1984, involved simply post-season allocation of catches between Taku River and Snettisham (Crescent and Speel River) stocks (Figure 3). The initial question was to what level does Crescent and Speel stocks contribute and are they segregated by area or time from the Taku River run. The past couple of years, with the implementation of the Pacific Salmon Treaty in 1985 and its provision that Canadian fishermen get 15% of the TAC to the Taku River, the application of SPA has evolved to be an in-season project which provides managers with weekly estimates of the Canadian (Taku) and U.S. (Speel and Crescent) contributions.

Table 2.--Presence of the brain parasite *Myxobolus neurobius* in returning adult sockeye salmon (*Oncorhynchus nerka*) for different spawning areas of the mainstem Taku River in southeastern Alaska and northwestern British Columbia, 1986. In parentheses is percent of sampled fish with the brain parasite by location; *N* = sample size.

Location		No. fish with parasite	*N*
U.S. Section[a]		19 (17)	109
Lower Canadian[b]		46 (78)	59
Middle Canadian[c]		37 (13)	286
Upper Canadian[c]		8 (15)	53
	Total	110 (18)	507

a/ Yehring and Fish creeks.
b/ South Fork Slough.
c/ King Salmon Flats side channel complex.
c/ Lower Nakina River side channels.

Table 3.--Freshwater age of returning adult sockeye salmon (*Oncorhynchus nerka*) for different spawning areas of the mainstem Taku River in southeastern Alaska and northwestern British Columbia, 1986. In parentheses is percent sampled fish by location and freshwater age; *N* = sample size.

Location	No. fish by freshwater age			
	0	1	2	*N*
U.S. Section[a]	6 (6)	96 (90)	4 (4)	106
Lower Canadian[b]	34 (55)	28 (45)		62
Middle Canadian[c]	196 (64)	104 (34)	4 (2)	304
Upper Canadian[d]	10 (24)	29 (71)	2 (5)	41
Total	246 (48)	257 (50)	10 (2)	513

[a] Yehring and Fish creeks.
[b] South Fork Slough.
[c] King Salmon Flats side channel complex.
[d] Lower Nakina River side channels.

Table 4.--Brood-year strength of returning adult sockeye salmon (*Oncorhynchus nerka*) for different spawning areas of the mainstem Taku River in southeastern Alaska and northwestern British Columbia, 1986. In parentheses is percent of brood-year fish by location and year, asterisk indicates <1.0%, and *N* = sample size.

Location	No. fish by brood year 1980	1981	1982	1983	1984	*N*
U.S. Section[a/]	1(1)	70(66)	34(32)	1 (1)		106
Lower Canadian[b/]		16(26)	23(37)	23(37)		62
Middle Canadian[c/]		33(11)	203(67)	67(22)	1(*)	304
Upper Canadian[d/]	2(5)	16(39)	18(44)	4(10)	1(2)	41
Total	3(*)	135(26)	278(54)	95(19)	2(*)	513

[a/] Yehring and Fish creeks.
[b/] South Fork Slough.
[c/] King Salmon Flats side channel complex.
[d/] Lower Nakina River side channels.

This SPA project compliments a mark-recapture project in the lower Taku River which estimates Taku River escapement.

In 1986, catches were classified in-season to Taku or Snettisham origin using 1985 data. The Taku River standard was built on scales from fish caught in fishwheels at Canyon Island. Temporal changes in stock composition of sockeye salmon passing through this lower river sampling site necessitated classification of fish using sequentially updated standards. Sufficient samples were available from 1985 collections to construct five separate standards for each two week time interval.

Andy McGregor's current post-season analysis has found good separation of District 111 catches into six groups: (1) Crescent Lake; (2) Speel Lake; (3) Kuthai Lake; (4) Trapper Lake; (5) Tatsamenie Lake; and (6) Taku River spawners. Classification accuracies for this 6-group model were 76% for age 1.3 fish and 66% for age 1.2 fish (compared to a 16.7% chance of randomly assigning fish in a 6-way model to the correct group). These two age groups comprised 73% of the catch, other age classes were classified based on differences in age compositions and the SPA classifications of these two age classes. Andy also classified Canadian commercial in-river gillnet catches to Kuthai Lake, Trapper Lake, Tatsamenie Lake, or river groups (mean classification accuracies were 73% and 80% for age 1.2 and 1.3 fish, respectively). The migratory timing results from SPA are being compared to that from the mark-recapture project.

River fish were classified least accurately, with scale patterns most similar to Speel Lake and Trapper Lake. Age 0. fish were only sampled from River escapements; age 0. fish in the catch were classified to the River group.

Incorporation of brain parasite (*Myxobolus neurobius*) prevalence in an age composition-SPA-brain parasite mixture model this coming season will probably improve accuracy of stock composition estimates. Alaskan stocks have a higher parasitism rate than Canadian stocks.

Classification totals of in-season models were comparable to those of post-season models although differences existed in some weekly estimates. Use of the four separate stock standards for Taku River groups should improve accuracies of in-season classifications this coming season.

Boundary Area Fisheries - SPA Found Most Cost Effective

Cooperative international U.S./Canada research programs were begun in 1982 to access several methods of estimating nation of origin of sockeye salmon caught in boundary area intercepting fisheries. These methods included adult tagging, GSI, brain parasite, and SPA. Scale pattern analysis has proved to be highly accurate, easily applied, and relatively inexpensive for estimating national origins and has been successfully used to estimate interceptions in all southern Southeast Alaska net fisheries since 1982. See Oliver and Jensen (1986) for description of 1985 analysis and references to earlier work.

Significant and persistent differences have been found in the freshwater and early marine growth of Alaskan and Canadian fish. Alaskan fish grow less and slower than Canadian fish. Little or no plus growth is found on scales from Alaskan fish since they do not have to migrate the long distances down the transboundary rivers that the Canadian fish do. These differences in growth allow easy and accurate separation of Canadian and Alaskan stocks.

Sensitivity analysis conducted for fish aged 1.3 in 1982 found model accuracies robust to the manner in which standards are constructed, therefore no prior knowledge regarding migratory pathways, stock abundance, or age composition was required to draw samples to represent each nation. Interannual variability in scale patterns is small and historical models have proven accurate for estimating interceptions.

The accuracy of our SPA based catch allocations was further tested in 1985 with a "blind test" classification of scale samples taken from fish of known origin. These known origin fish were ones that were tagged and subsequently recovered in conjunction with the U.S./Canada adult tagging project in 1984. Our SPA models performed admirably, the true stock composition proportions were within the 90% confidence bounds of all "blind test" classifications.

Seine and gillnet catches from southern Southeast Alaska Districts 101 to 108, have been classified to nation and/or system of origin based on analysis of age compositions and scale patterns since 1982. Separate age specific LDF models are constructed for fish aged 1.2, 1.3, 2.2, and 2.3. These four age classes comprise 95-99% of the catches. All LDF models are based on current year standards.

Mean classification accuracies are consistently better than 90% for 2-way Alaska vs. Nass/Skeena models, better than 80% for 3-way Alaska vs. Nass/Skeena vs. Tahltan or Stikine models, and better than 75% for the 4-way models. Misclassifications are usually highest between the Canadian groups.

District 108, 106-41, and 106-30 gillnet catches are classified to Alaska, Nass/Skeena, Tahltan, and Stikine (non-Tahltan) origin. Seine and gillnet catches in all other districts are classified to Alaska and Nass/Skeena origin. Samples from runs to 28 Alaskan rivers (Figure 4) are combined in equal proportions to construct the Alaska standard and samples from Nass and Skeena Rivers are combined in equal proportions to construct the Nass/Skeena standard.

In 1985, Nass/Skeena fish dominated catches in District 101 gillnet (69%) and 104 seine (78%) fisheries (Figures 5 and 6) while Alaskan fish dominated catches in Districts 101 (82%)(Figure 7), 102 (78%), and 103 (75%) seine fisheries. Alaskan fish contributed 48% of the District 106-30 and 106-41 catches and Tahltan and Stikine fish comprised less than 11% of the catches in these districts (Figures 8 and 9).

<u>District 106 and 108 Gillnet Fisheries - In-season SPA Estimates for a Minor Contributing Stock</u>

In response to the Pacific Salmon Treaty mandate that Canadian fishermen are entitled to 35% or 10,000 fish (whichever is greater) of the TAC of Stikine River sockeye salmon, we began a project in 1984 to estimate interceptions of Stikine River fish in-season in District 106 and 108 gillnet fisheries. Under Glen Oliver and Kathleen Jensen's supervision, this project has succeeded in providing fishery managers with stock composition estimates from each weekly fishery within 48 hours of the fish being landed.

The past two seasons, separate allocations were made for Districts 106-41 (Sumner Strait) and 106-31 (Upper Clarence Strait). Catches were allocated to Tahltan, Stikine, Alaska, and Nass/Skeena origin. In-season models have generally performed accurately when compared to post-season models (point estimates nearly always fall within the 90% confidence bounds of the post-season models). The stock composition of District 106 and 108 test gillnet catches has also been routinely estimated by project personnel. These estimates are particularly valuable for weeks that the commercial fishery is closed.

Despite the District 106 fishery being the major U.S. intercepting fishery for sockeye salmon bound for the Stikine River, Stikine fish generally comprise a small, less than 15%, of the District 106 harvest. The small relative contribution of Stikine fish has "tested" the accuracy of our models. As for the Taku Inlet fishery, the inclusion of brain parasite data in an age-SPA-brain parasite model should improve model accuracy and permit the discrimination of additional stocks.

CONCLUSION

Scale pattern analysis has proven to be highly accurate, easily applied, and relatively inexpensive for estimating origins of sockeye salmon in several Southeast Alaska fisheries. Results from SPA projects are important in the in-season management of sockeye salmon gillnet fisheries in Districts 115, 111, 108, and 106 and for post-season allocation of catches in in all southern Southeast Alaska gillnet and purse seine fisheries. Significant and persistent differences have been found in the freshwater and early marine growth of Alaskan and Canadian fish, enabling accurate estimation of national contributions and fulfillment of the Pacific Salmon Treaty requirements to estimate interceptions. Furthermore, success at separating major Canadian and Alaskan runs (ie. Tahltan, Stikine, Nass, Skeena, McDonald, and Hugh Smith) based on SPA and age composition alone or in combination with brain parasite and/or genetic data appears promising and of value both for compliance with the Treaty and for domestic management needs.

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Oliver G.T. and A.J. McGregor. 1986. Estimated contribution of transboundary river sockeye salmon stocks to commercial fisheries in Alaska Districts 106 and 111 in 1985, based on scale pattern analysis. 30 pp. In: Final 1985 U.S./Canada Research Report for Contract No. 85-ABC-00142. Alaska Dept. of Fish and Game. Juneau, Alaska.

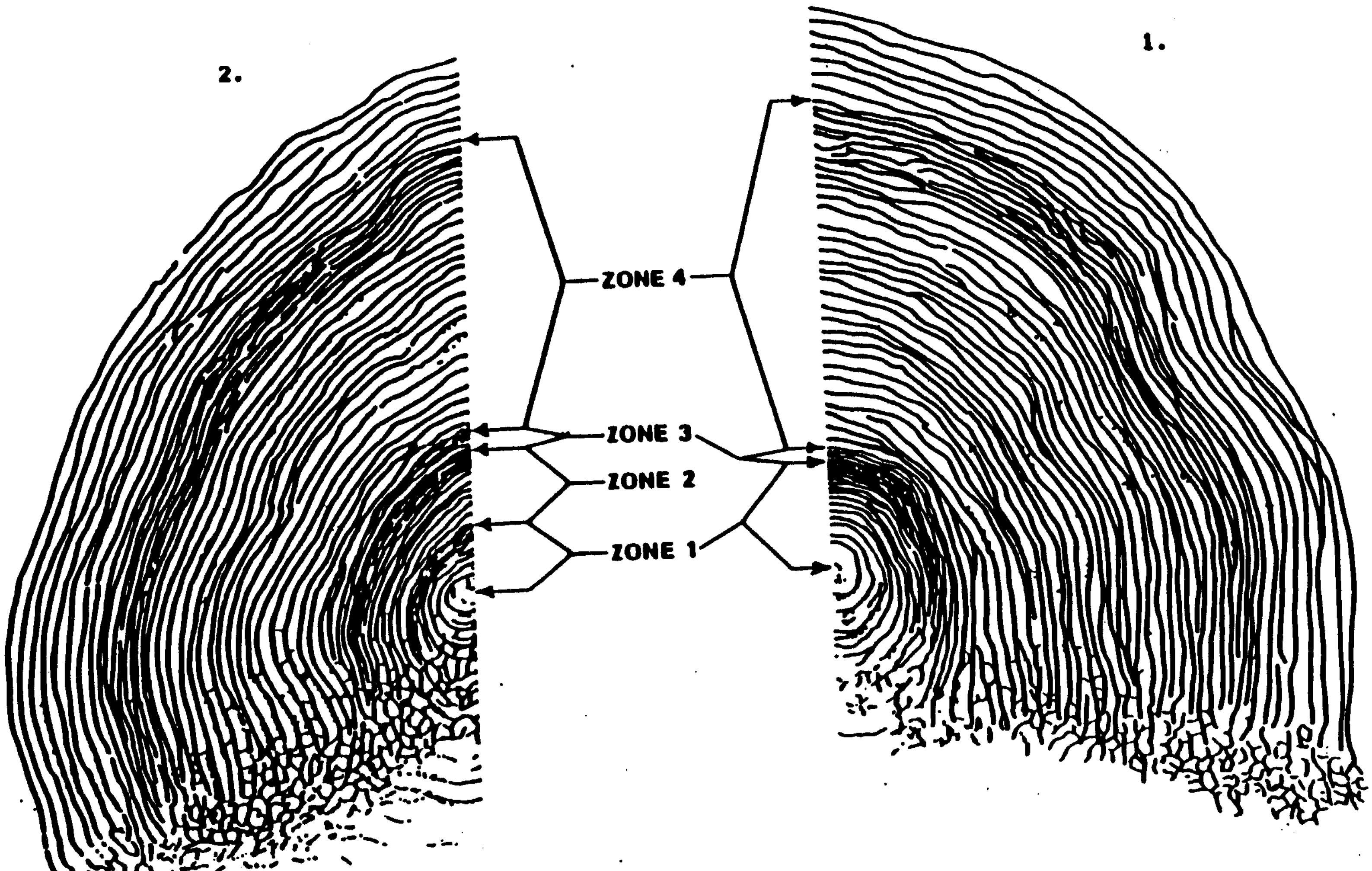

Figure 1. Typical scale for age 2. and 1. sockeye salmon showing the zones used to measure scale patterns.

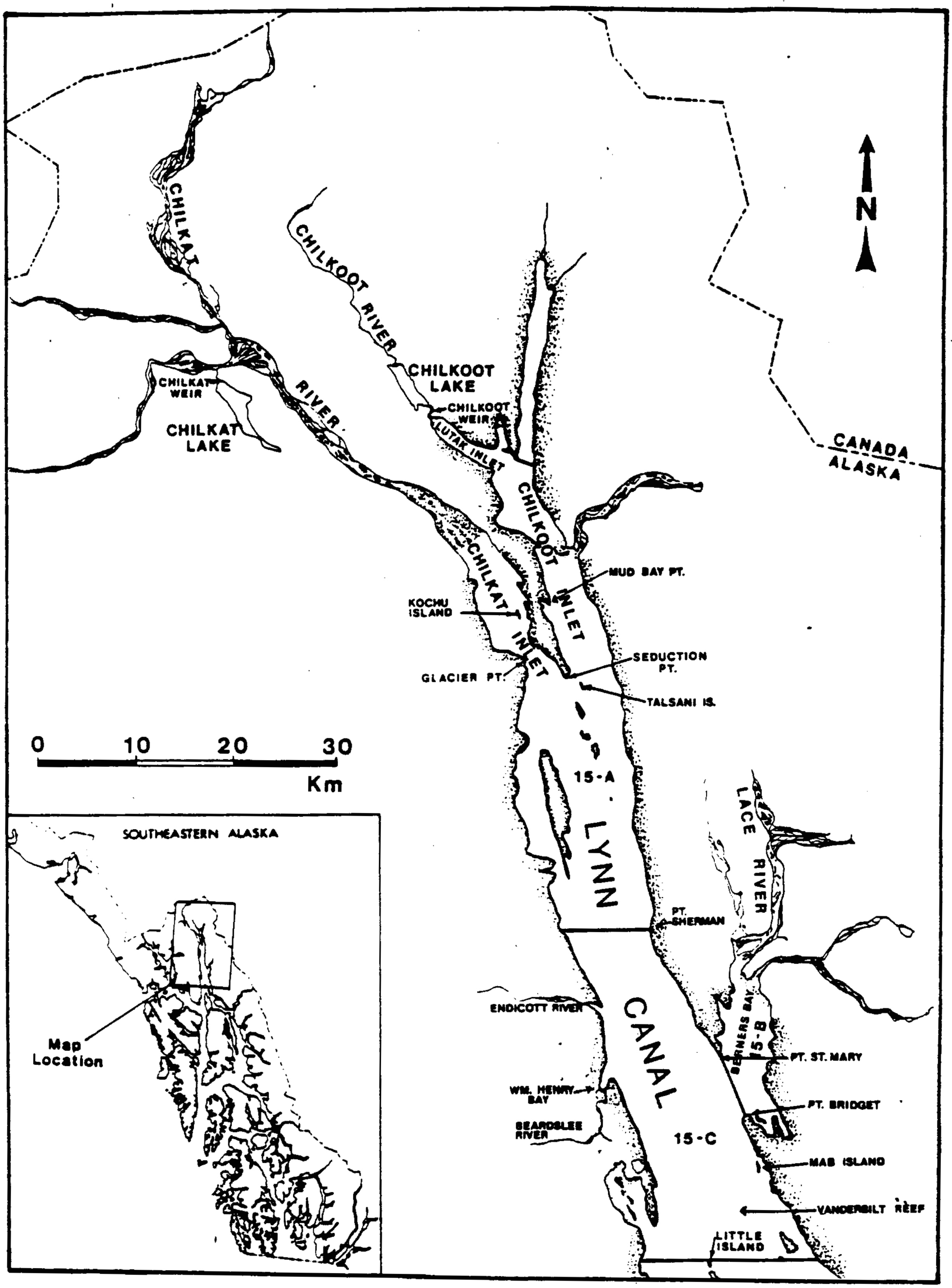

Figure 2. Map of Lynn Canal showing the fishing district and sections and principal spawning and rearing areas.

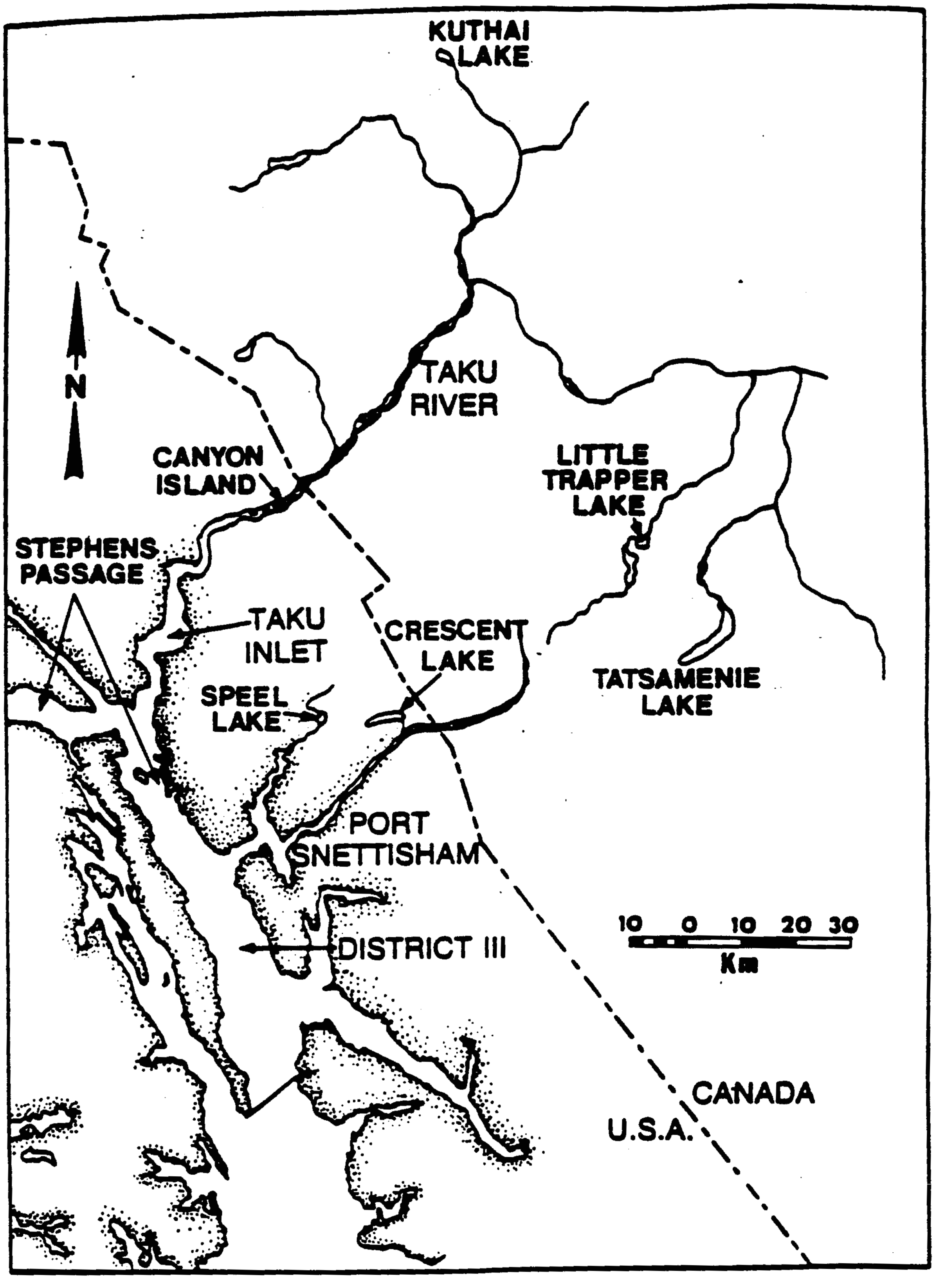

Figure 3. The Taku River, Port Snettisham, and adjacent fishing areas.

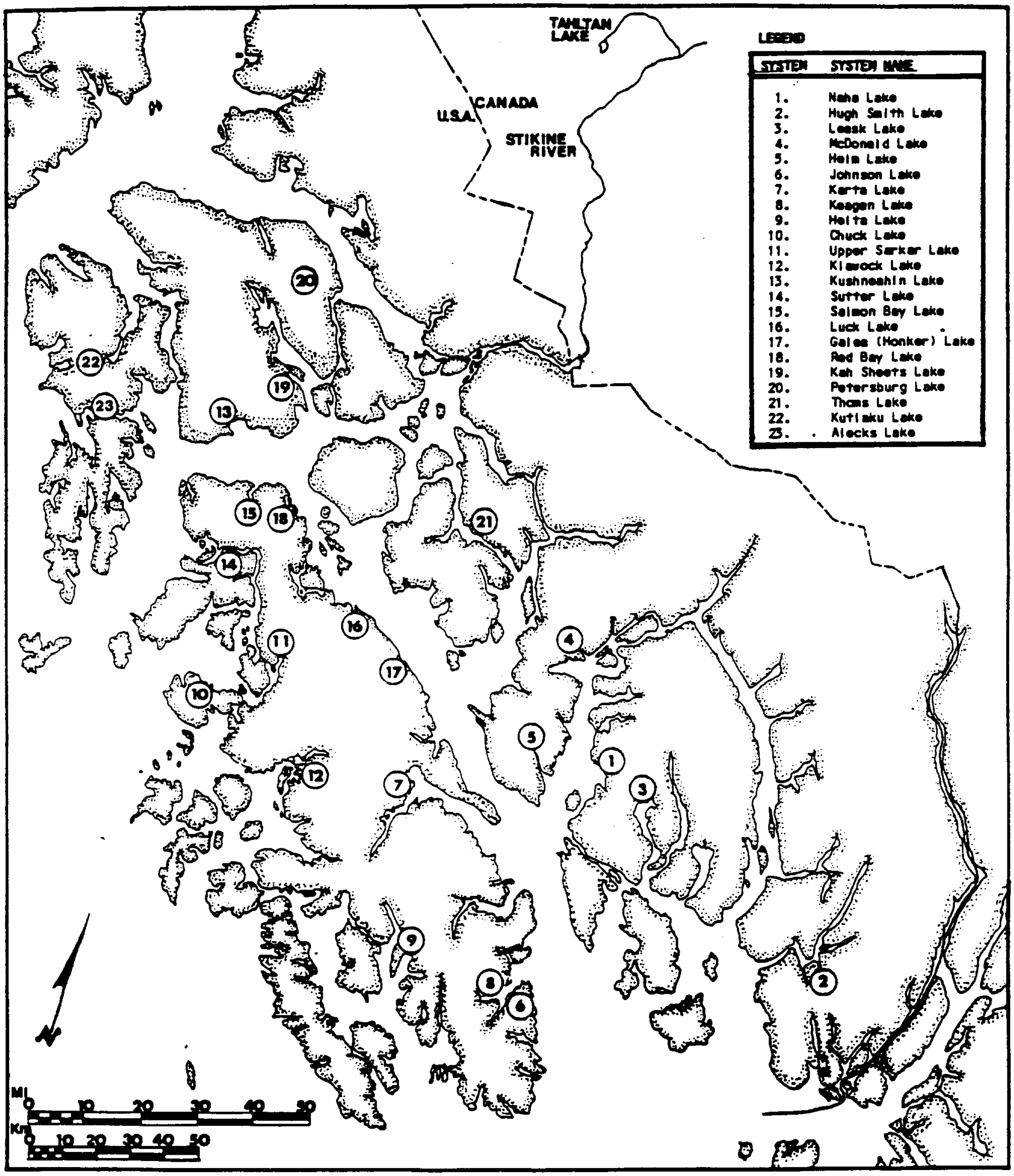

Figure 4. Sockeye salmon stocks included in the Alaska standard.

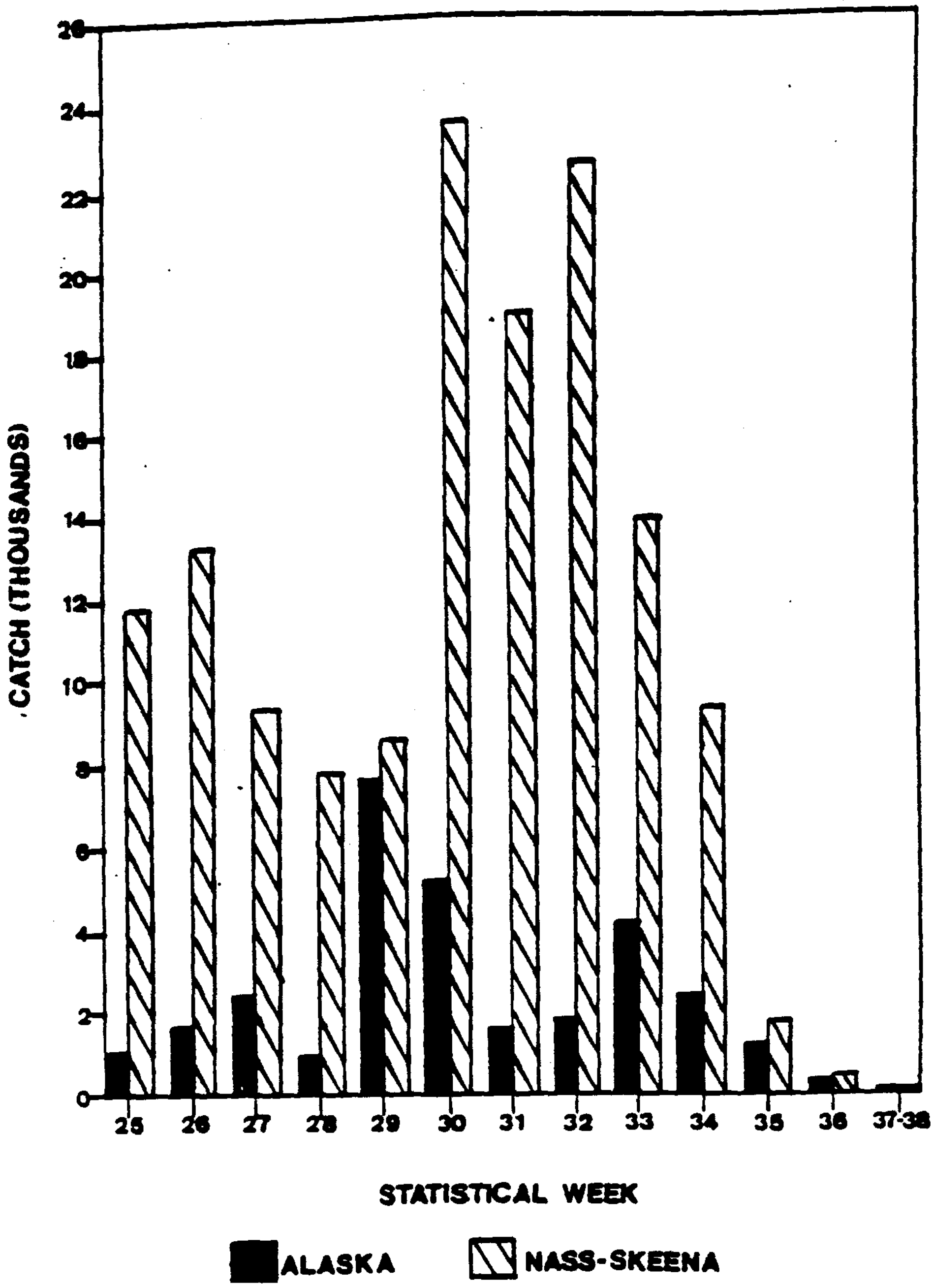

Figure 5. Weekly catch by stock in Alaska's District 101 gillnet fishery, 1985.

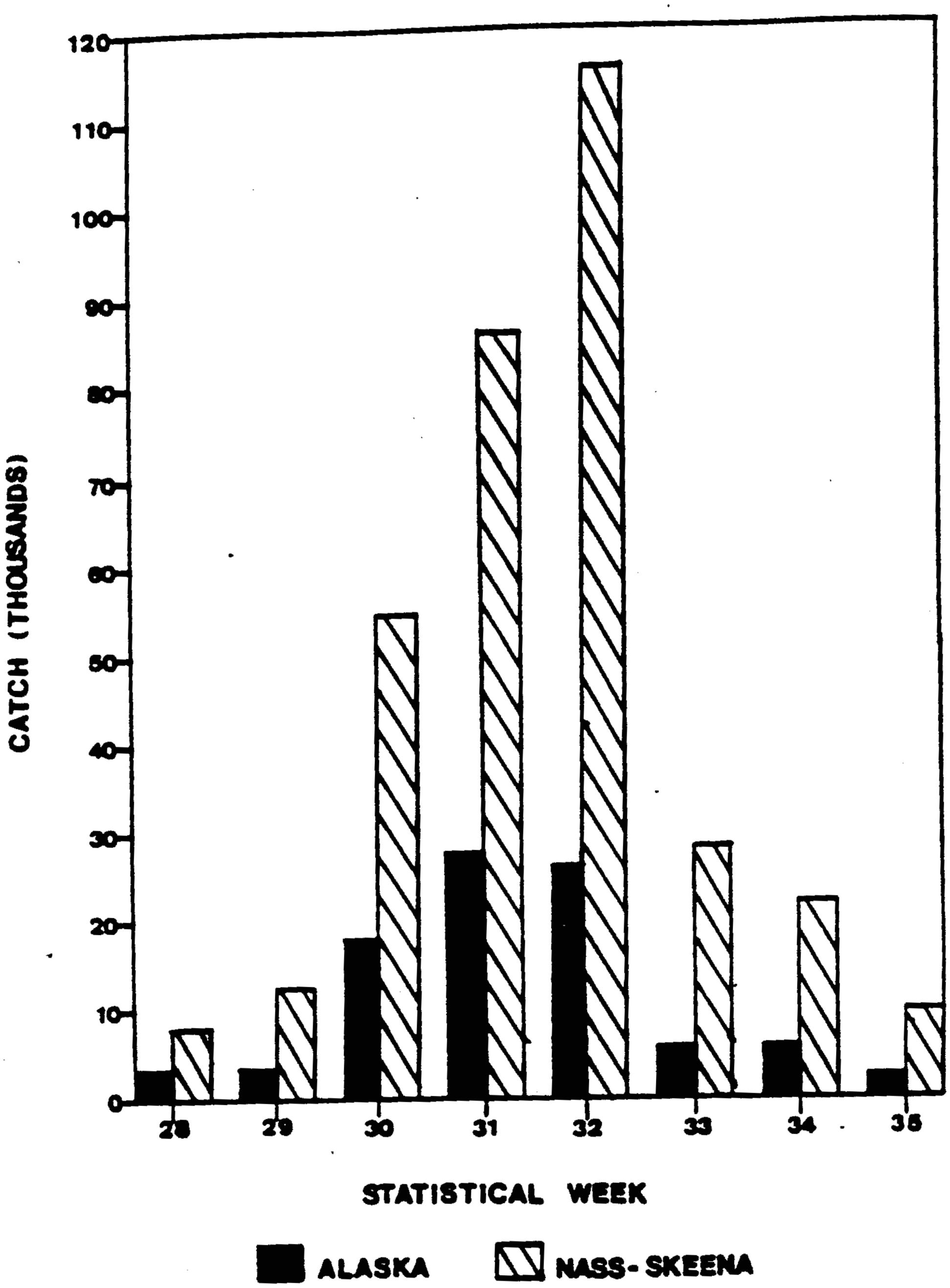

Figure 6. Weekly catch by stock in Alaska's District 104 purse seine fishery, 1985.

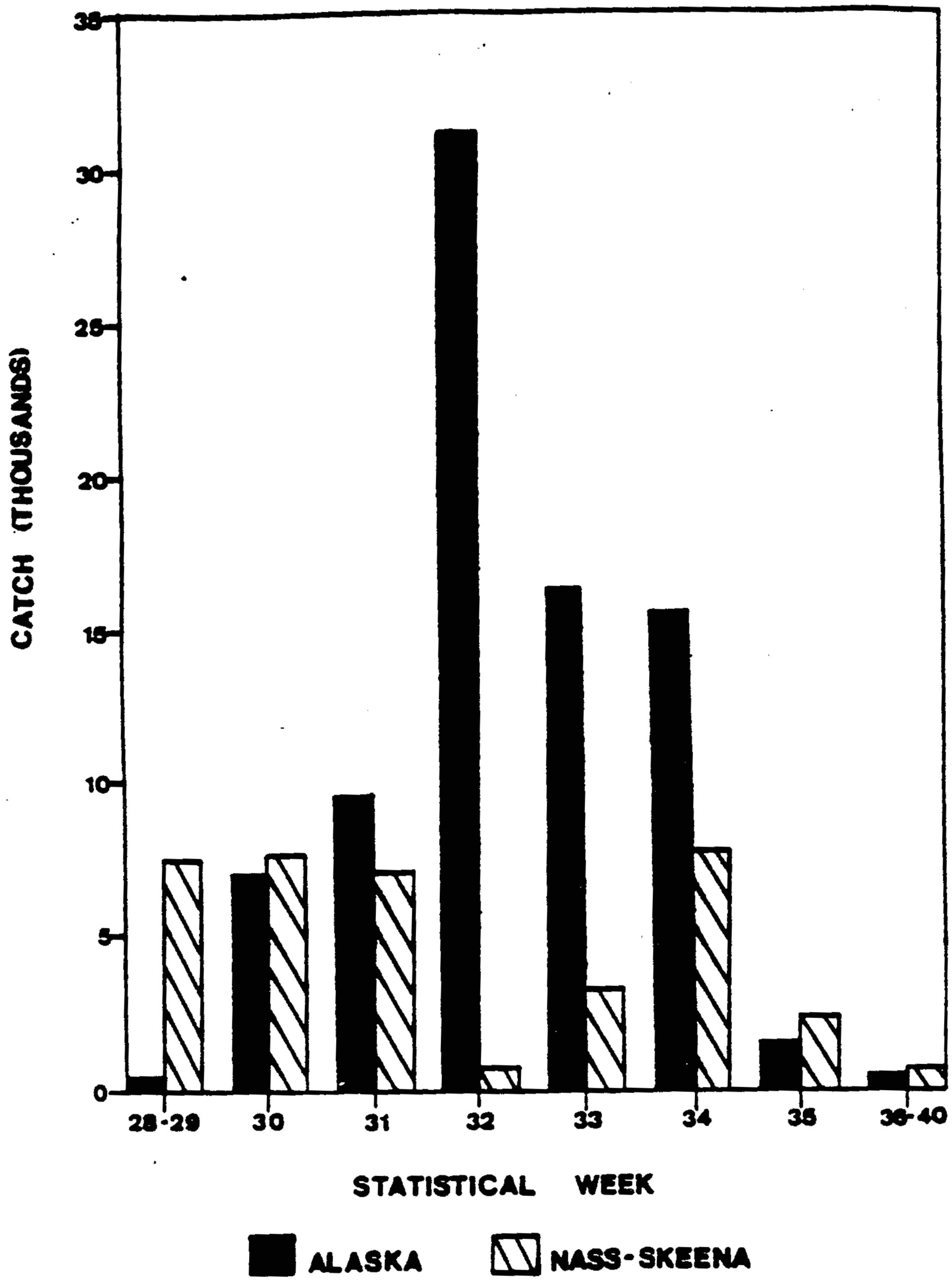

Figure 7. Weekly catch by stock in Alaska's District 101 purse seine fishery, 1985.

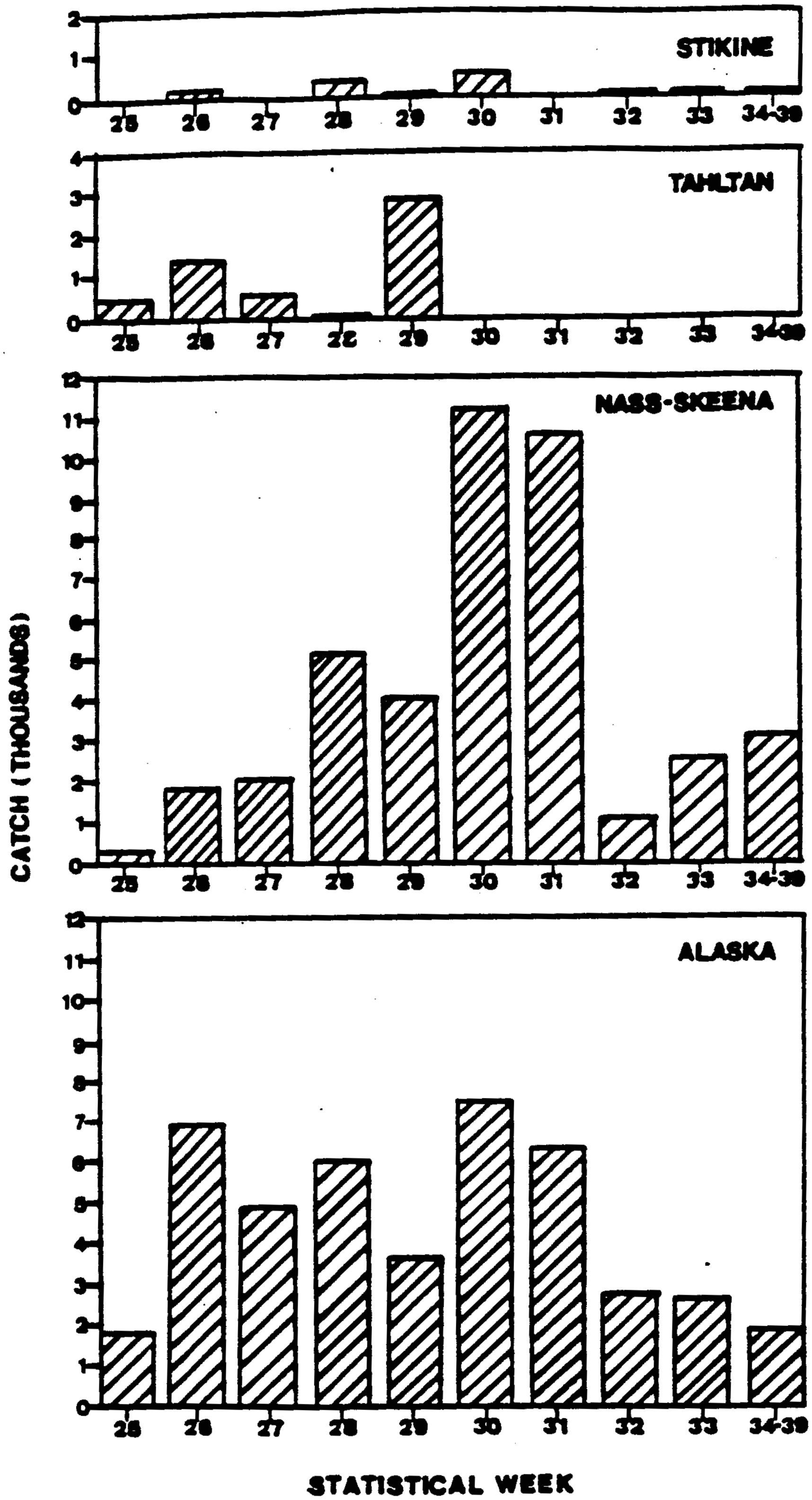

Figure 8. Weekly catch by stock in Alaska's District 106-30 gillnet fishery, 1985.

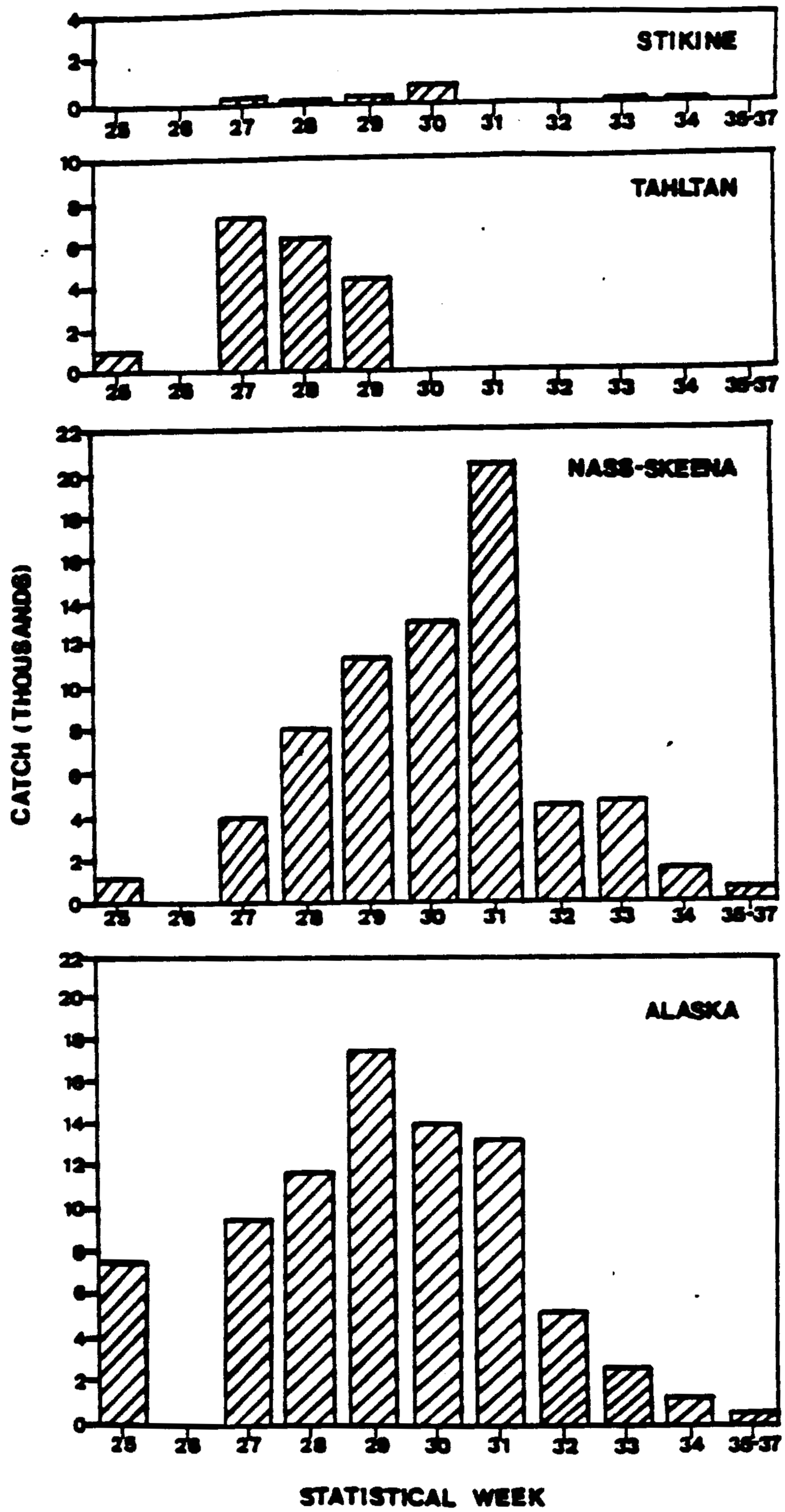

Figure 9. Weekly catch by stock in Alaska's District 106-41 gillnet fishery, 1985.

BRISTOL BAY SOCKEYE MANAGEMENT PROGRAM

Doug Eggers
Alaska Department of Fish and Game
Commercial Fisheries Division

MEMORANDUM

State of Alaska

DEPARTMENT OF FISH AND GAME

TO: Ken Parker
Director
Division of Commercial Fisheries
Department of Fish and Game

DATE: May 11, 1987

FILE NO.:

TELEPHONE NO.: 465-4210

SUBJECT: Revised Memo:
Eggers to Parker
Dated 2/19/87

FROM: Doug Eggers
Fishery Scientist
Division of Commercial Fisheries
Department of Fish and Game

Subject: Benefits and Costs of the Commercial Fisheries Division Program --- Experience in Bristol Bay Sockeye Salmon. This is a revised version of original memorandum.

EXECUTIVE SUMMARY:

A minimum estimate of the value of additional dollars invested in the Alaska Department of Fish and Game (ADF&G), Division of Commercial Fisheries program of Bristol Bay management and research at the FY 85 funding level is that for every additional $1 invested in ADF&G's program results in increased catches worth $23 to the fishermen and $43 to the processors.

I have finished the cost/benefit analysis of the Division of Commercial Fisheries program in Bristol Bay. The approach was to develop computer models with stock dynamics, as well as levels of management precision implicit to simulate catches. To fully document the model and simulation results will require a rather lengthy manuscript. Because of prior commitments of my time, I will not be able to finish the manuscript in time for the necessary budget defense. The following is a brief abstract of the approach and results (in memorandum form) for use in defending our program, and is complimentary to the work that Gordon Kruse is completing.

The following arguments are based on compensatory stock recruitment dynamics, and therefore, the qualitative recommendations on level of investment and management approach would apply to any stock of fish that has a highly compensatory stock recruitment relationship.

Introduction

Except for the Kvichak cycle years, where high escapement levels have always been achieved, there has been a steady decline in Bristol Bay catches of sockeye salmon from the 1930's, following buildup of the fishery, to the early 1970's (Fig.1) when catches were at historically minimum levels. This decline in catches is thought to be the result of low production due to either interceptions in the Japanese high seas fishery being higher than documented or poor environmental conditions or both, contributing to the inability to maintain adequate escapement levels during years of poor return in face of the intense inshore fishery. Since the early 1970's the Bristol Bay stocks have recovered and the production is close to maximum sustainable levels. This has resulted from more precise management under which escapement levels were maintained during the disastrously low return years of 1971 through 1975, that resulted in the severe restrictions placed on the inshore fishery, the ten-fold reductions in high seas interception beginning in 1974, and very high production due to a combination of favorable environmental conditions and reduced high seas interceptions.

Because of the long history of highly intensive management and quality of the historical data base that has resulted from the State of Alaska and industry investment in stock assessment and fisheries monitoring, we have been able to develop and implement the management decisions that have brought about the rebuilding of the Bristol Bay sockeye salmon stocks to the present high levels of production. However, the Bristol Bay management system that has been on line since statehood does cost money. The peak level of Bristol Bay expenditures (I am assuming that roughly 10 percent of Commercial Fisheries general fund expenditures was for Bristol Bay sockeye salmon) was in FY 85, and was approximately $1.88 million per year. Between FY 67 and FY 85 there was an almost continuous increase (roughly $78.3 thousand per year) Bristol Bay expenditures (Figure 2). Note that I am using past expenditures adjusted for inflation and standardized to 1986 $$$ based on the Anchorage consumer price index.

With the large reductions in the commercial fisheries budget that are being considered, we must question the approach, as well as the level of investment that the division is using to manage fisheries. Are more cost-effective management approaches available? If not, what does the reduction in programs that have taken place since FY 85 mean in terms of actual costs to the industry? I have undertaken an analysis to address these questions for Bristol Bay. In Bristol Bay, the length of the time series and quality of total return data by age class and river system is sufficient for the development of models of the stock's response to exploitation, so that the actual returns expected under alternative management scenarios can be evaluated.

Brief Description of the Simulation Model

The model used here was adapted from the model used (Eggers and Rogers, 1987) to evaluate the Kvichak cycle and ADF&G historical management policy for that system. The form of the model is a computer program that recursively constructs the current run from production of previous brood years, allocates the run to catch and escapement, then projects the future year returns from that escapement. For each year simulated the returns constituting the run are collected. The Bristol Bay run consists of four major age classes from three brood years including 1.2 (age 4), 2.2 (age 5), 1.3 (age 5), and 1.3 (age 6). The run is then allocated to catch and escapement based on a harvest submodel. The total returns from a given escapement are calculated using the spawner/recruit submodel. The total returns are then allocated to specific age classes and future run years based on age at return submodel. Note the model used here has natural variation implicit in the spawner recruit, age at return, and harvest submodels.

Spawner Recruit Submodel.

A model was built for five river systems or stocks including Ugashik, Egegik, Naknek, Kvichak, and Nushagak. The latter is the pooled runs of the Nushagak District, including the Igushik, Wood and Nuyakuk Rivers. The Kvichak stock has implicit brood year interaction, and the model used by Eggers and Rogers (1987) was used for this study. In each of the other stocks there is a significant depression of return per spawner at high escapements (Fig. 3), hence, simple compensatory stock dynamics were used for each of these stocks, except for the Kvichak. A simple Ricker curve was fit by nonlinear least squares to the escapement return data for the 1974 through 1981 brood years, (Fig. 4 through 7). The analysis was restricted to the more recent years because of insignificant high seas interception for those runs, and therefore, these data are believed to be more indicative of returns expected from alternative management policies. Natural variation in production was modeled as random deviations from the implicit spawner recruit submodel.

Age at Return Submodel.

The same general relationships used in the Kvichak age at return submodel hold for the other Bristol Bay stocks.

> Freshwater Age - In all Bristol Bay river systems freshwater age (%1.) was positively correlated with temperature during the lacustrine residence of the progeny of the respective brood year, (Fig. 8 - 9). A time series model was used to generate temperatures. Freshwater age was then calculated from the fitted regression of freshwater age on temperature.

Ocean Age - In Kvichak model ocean age (%.3) was positively correlated with temperature and negatively correlated with escapement. The same relations, with varying degrees of correlation, hold for the other Bristol Bay stocks. In Ugashik, ocean age was a simple linear regression of ocean age against freshwater age. In Egegik, ocean age was a multiple regression of ocean age against freshwater age and escapement. In Naknek, ocean age was a simple linear regression of ocean age against freshwater age. In Nushagak, ocean age was not related to any of these variables, and was taken to be the historical mean and with associated natural variation. In Ugashik, Egegik, and Naknek natural variation was taken to be random deviations from the respective regression model.

Harvest Submodel

In the Kvichak model management error was taken to be the difference between the realized rate of exploitation and the target rate of exploitation. The management error has been highly variable, but consistent among Bristol Bay fishing districts (Fig. 10). These were pooled among fishing districts over the years 1962 to 1985 (Fig. 11). The management error had a normal distribution for years where the return was greater than the escapement goal, and had a uniform distribution for years where the return was less than the goal. In the latter case it is not possible to have a negative management error. In the actual escapements deviated randomly from target escapement goals based on the probability distributions for management error (Fig. 11).

Evolution of The Commercial Fisheries Bristol Bay Program

The management policy for Bristol Bay sockeye salmon has progressed from fixed 50 percent rate of exploitation implemented with limited fishing time under federal regulatory authority to intensive management for stock specific escapement goals implemented with time/area closures under State of Alaska Emergency Order Regulatory Authority. The exact evolution of the harvest policies is documented in Table 2. It is clear that the present program is more expensive and more information intensive than earlier programs. The present program is integration of real time assessment of run strength, continuous evaluation of harvest policy, and striving to achieve maximum sustained yield. Ongoing analyses suggest that catches can be increased by changing the 1984 harvest policy. Specifically, these changes involve increasing the Ugashik escapement goal and altering the cyclic escapement goal policy used to manage the Kvichak run.

In addition to these changes in management policy, we have become more effective in implementing management policy. The magnitude of management error has declined over time (Fig. 12) as the funding level of the commercial fisheries program has increased. To provide quantitative estimates of the yearly decrease in management error a time series of the absolute value of the management error was constructed. Mean management errors for adjacent years was substituted for the errors observed for the strike years 1969, 1979, and 1980. A three-year moving average was taken to identify more clearly the downward trend in management error. A regression line was fitted to this data (Fig. 13), and the slope of the line indicated that on an average we have achieved an 0.8 percent per year reduction in absolute management error as the Bristol Bay program has grown. Management error has declined from 25 percent in 1960 to 7 percent in 1985. It is straightforward, mathematically to express the mean absolute management error in the range (25 percent to 7 percent) in terms of the standard deviation of the respective probability distributions for management error, which is both positive and negative (Fig. 11). Thus, one can easily simulate the catches expected from programs of varying levels of management precision.

Evaluation of the Bristol Bay Program

The Bristol Bay program has evolved in two dimensions. The first is an evolution of management policy, and the second is improved precision in management. The first function is largely carried out by research personnel and involves collection, maintenance, and analysis of long term stock assessment data. The second function is largely carried out by management personnel and involves inseason implementation of the current management policies. These activities are perceived to be separate by many individuals. They are separate in that different skills and training are required by the respective individuals, but the same data and information is used to carry out these activities. The following will demonstrate, beyond any doubt, that these activities are highly integrated and complimentary. Both functions are essential elements of the Bristol Bay program.

The computer simulation model was used to calculate harvest levels expected under alternative management policies and levels of precision by which these policies can be implemented. Computer simulations were conducted under four harvest policies (Table 2).

1. fixed 50 percent rate of exploitation under White act management;

2. cyclic escapement goals for the Kvichak, and fixed escapement goals for the other systems with the 1965 goals;

3. 1965 cyclic escapement goals for the Kvichak and 1984 fixed escapement goals for the other systems;

4. 1965 cyclic escapement goals for the Kvichak, 1984 fixed escapement goals for the other systems except Ugashik, and 1.5 million for the Ugashik goal. Note the theoretical maximum sustained yield harvest policy identified by Eggers and Rogers (1967) was not considered because of the preliminary nature of the analysis of the socioeconomic aspects of implementation. The simulations were conducted for each of these policies, at levels of management precision from 0 percent (i.e., perfect management) to 20 percent (early sixties precision). Since the simulation model is stochastic with natural variation implicit, actual values of simulated catches varied between simulations. The catches presented here were the average of 150 simulations, with each simulation calculating a 106 year time series of catch expected under the respective management policy and level of management precision.

The results of these simulations are shown in Figure 14. There are several extremely interesting things that emerge from these simulation results.

The first point that emerges from Figure 14 is that substantial benefits, in terms of increased catches, have resulted from changing management policy and reducing management error.

The second point that emerges from Figure 14 is that we have quantitative estimates of the marginal benefits (Fig. 14) in terms of increased yield to industry resulting from increases in management precision and improving management policy. These can be compared to the marginal costs of achieving these improvements in management and cost benefit ratios constructed. In the evolution of the Bristol Bay program, reductions in management error and more productive harvest policies occurred together. So, cost benefit ratios must be couched in time rather than specific harvest policies or management errors. I have done this in Table 3. I selected the times that management policies were changed, 1960, 1965, 1984, and the proposed changes in Ugashik management policies to be discussed at the 1987 staff meeting. I calculated the increase in average catch in numbers and ex-vessel (assumed 6 pound average weight and $1 per pound price), accompanying the change in management policy and used the level of management precision that was available under the program at the time of the policy change. I assume that it cost $86 thousand in additional funding to achieve a 1 percent reduction in management error. This figure was based on the ratio of average annual increase in expenditure (Figure 2) and the average reduction in management error (Figure 13). These figures, in my opinion, are the best measure of the marginal benefits for marginal expansion of the program. The cost benefit ratios actually increase from 18 to 36 as the program evolves. If one compares these cost benefit ratios to the substantially lower cost benefit ratios (generally less than 2) that Hartman (1986) found in his evaluation of the FRED hatchery system, one must conclude that the most cost effective investment for Alaska's salmon fisheries is the continued investment in ADF&G Commercial Fisheries program.

As an additional exercise, I constructed a cost benefit analysis for alternative FY 88 budget scenarios. The alternative FY 88 budget scenarios considered here were:

1. FY 85 funding of $1.88 million per year. Under this scenario the 1984 harvest policy could be implemented with an average management error of 7 percent.

2. The Governor's requested FY 88 funding of $1.43 million. Under this scenario we can implement the 1984 policy. However, management error can be expected to increase to 12 percent. As shown in Table 3, the catches expected under the management of the Governor's FY 88 funding will decrease by 2.3 million fish, and the $30 million will be lost to the fishermen for each dollar that the budget is decreased.

The last point that emerges from Figure 14 is that the relative benefits from investing in improving management policy versus investment in improving management precision is different over the evolutionary history of the fishery. Early in the history of the Bristol Bay program the greatest increases in catches resulted from moving to more optimal policies. At that time the management policies were not optimal and there was relatively lower increases in catch accompanying increases in management precision. However, as management policies approached optimal harvest policies as the program evolved, there was a relatively greater increase in catches accompanying increases in management precision. In layman's terms, there is little payoff for precisely managing an incorrect policy. On the other hand, if the optimal harvest policy is known, then there is a much larger payoff for precisely implementing the policy. This says to me that in the early stages of program development the priority should be on stock assessment and data collection, and in analysis of the optimal harvest policies, and in the later stages of program development the priority should be on improving inseason management.

The priorities that I am suggesting above does not suggest that we trash the local management programs in favor of research. We should seek ways to fund additional stock assessment and fishery monitoring programs in places where these programs are underdeveloped. We should also strive vigorously to implement stock assessment and fishery monitoring programs where they are currently inadequate, or do not exist. In so doing, the improvements in management will automatically accompany the improvements in data collection and analysis. After all, the same data is used for both ends. The activities of harvest policy evaluation and in season management are fully complementary. According to Figure 14 it doesn't make any sense to improve inseason management without harvest policy evaluation, and once the harvest policies are on line the most productive activity is improving management precision.

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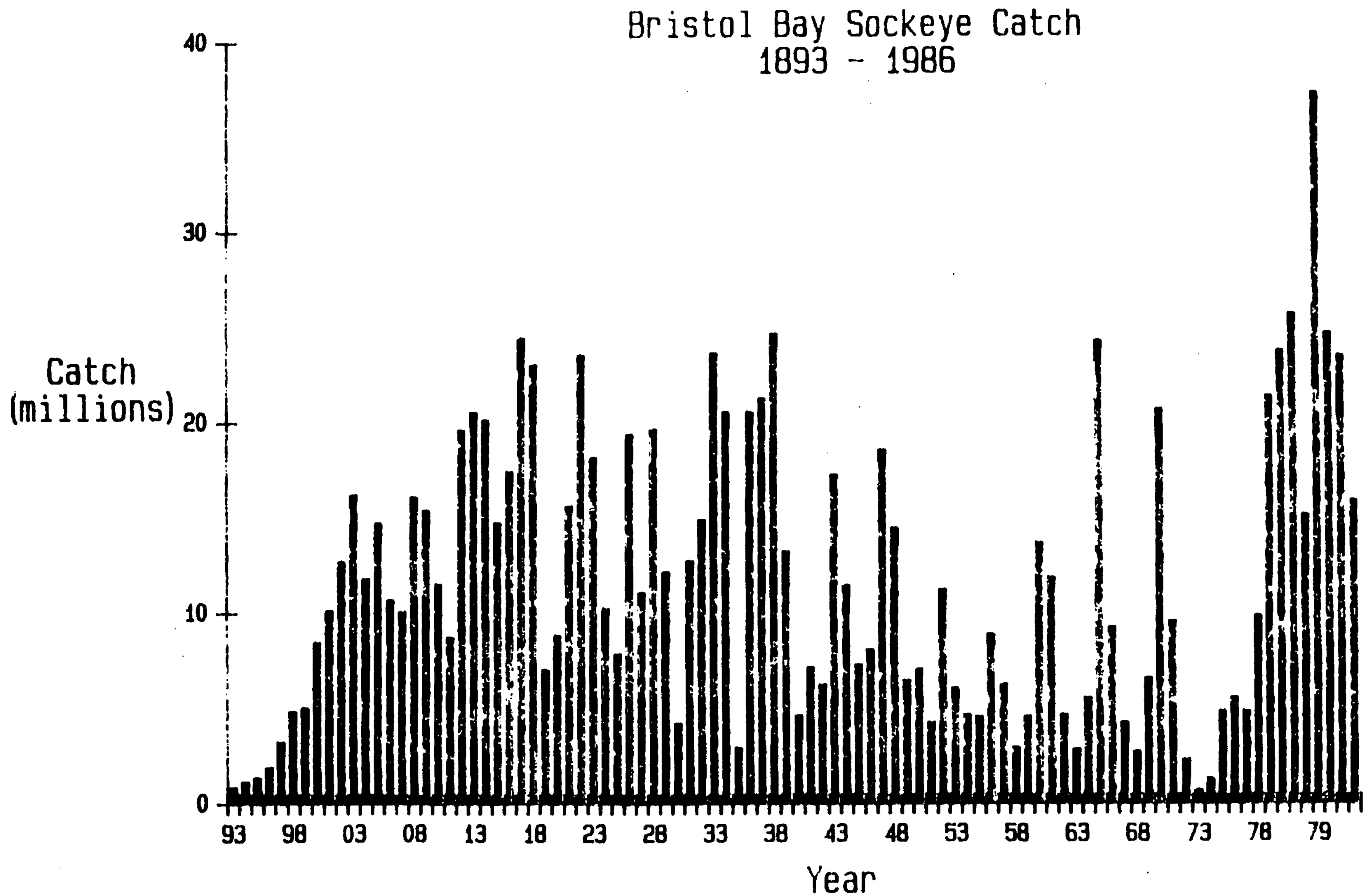
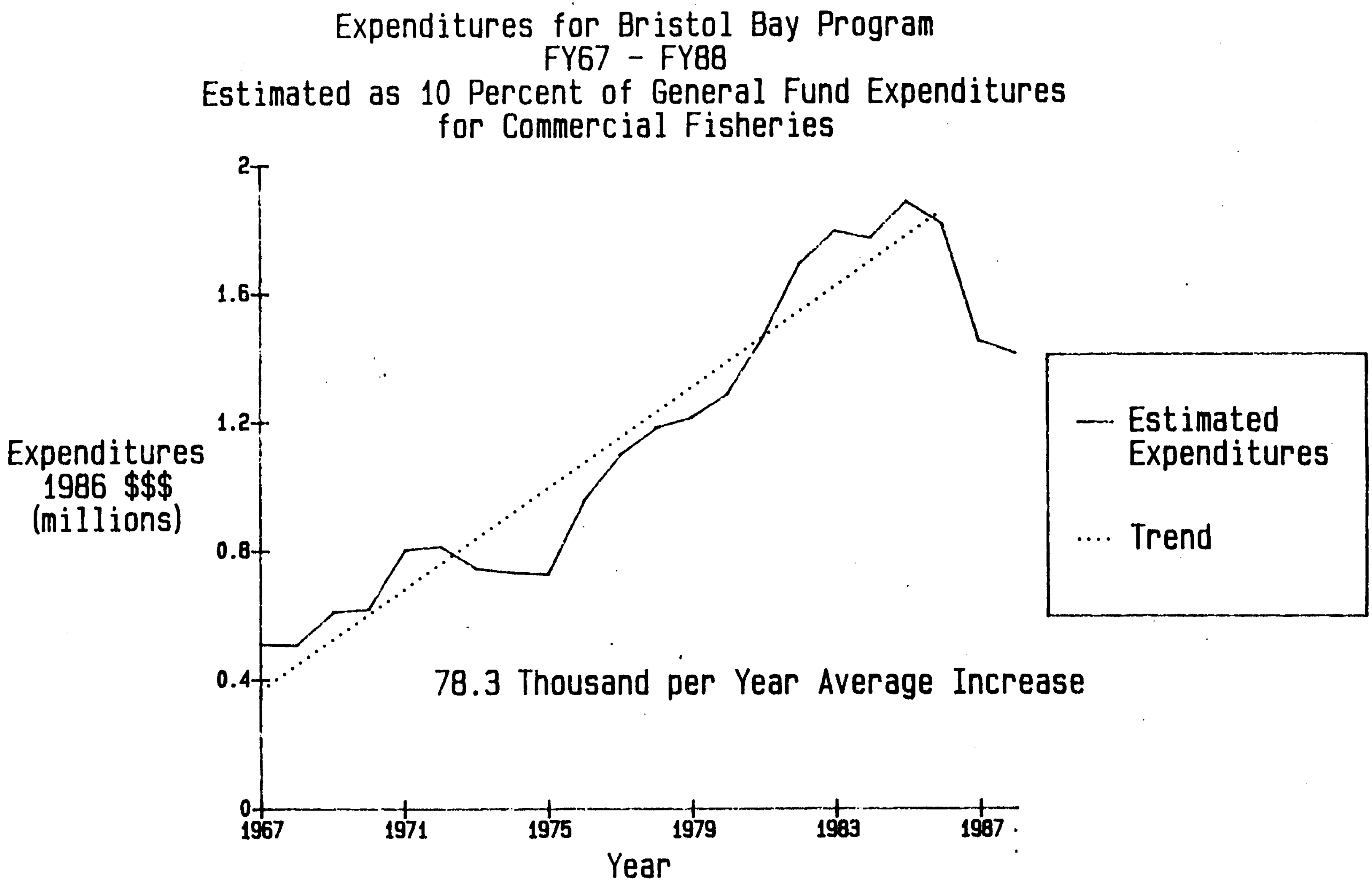
cc. Pennoyer
Mundy
Regional Supervisors
Regional Research Biologists
Kruse
Rigby
Bristol Bay Staff



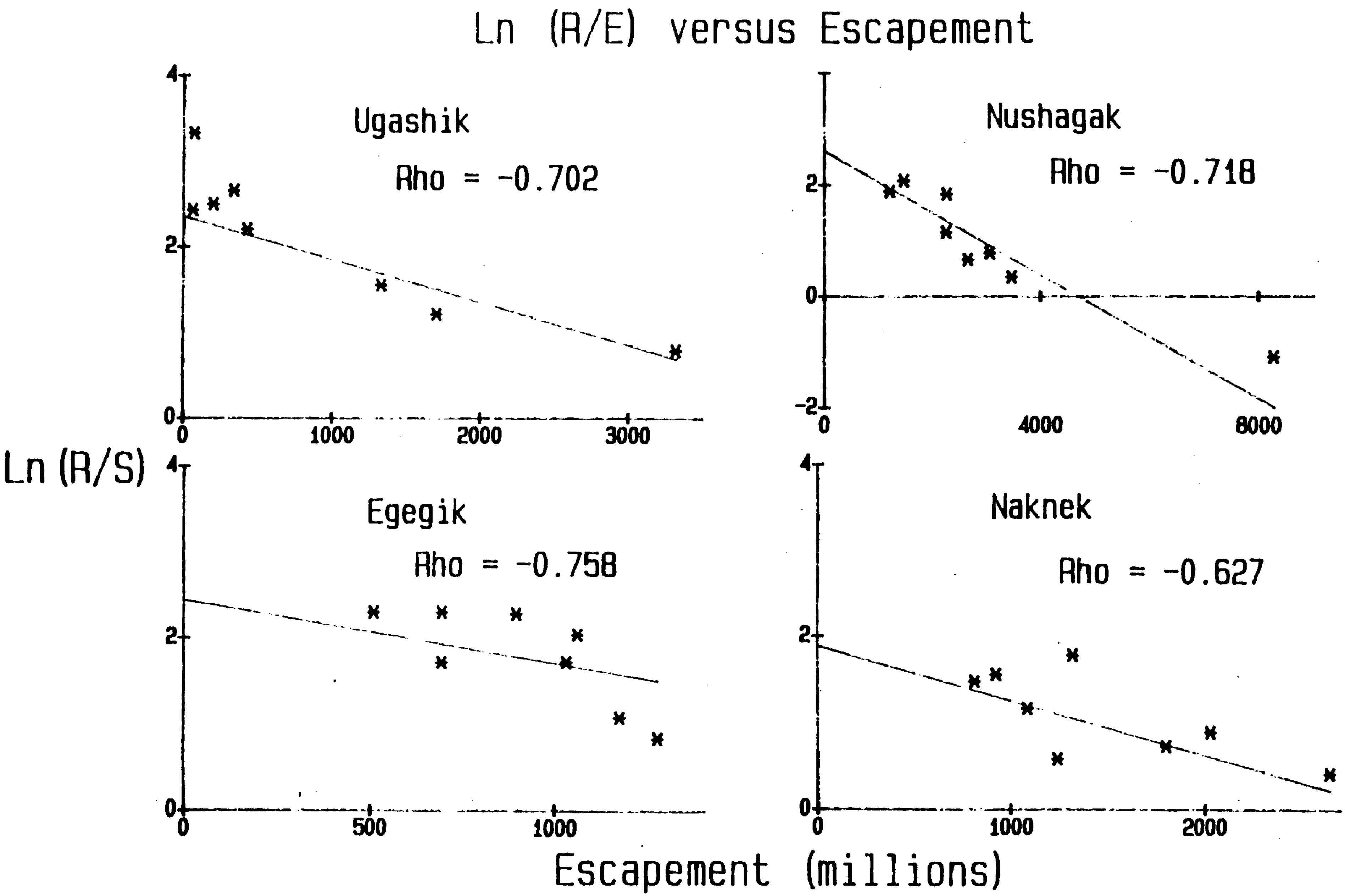
Bristol Bay Sockeye Catch
1893 - 1986
Catch
(millions)
40
30
20
10
0
93
98
03
08
13
18
23
28
33
38
43
48
53
58
63
68
73
78
79
Year

Figure 1



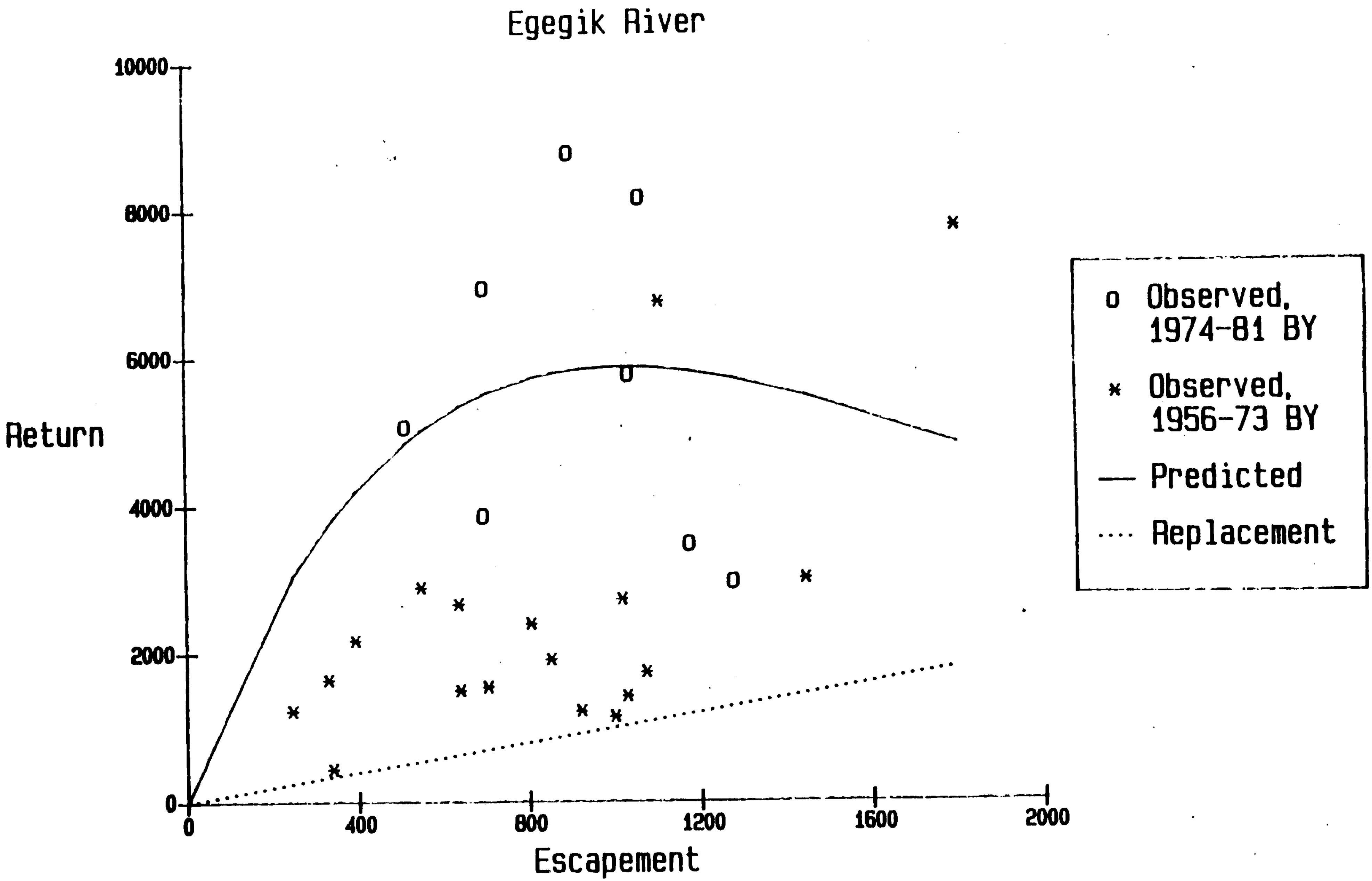
Expenditures for Bristol Bay Program
FY67 - FY88
Estimated as 10 Percent of General Fund Expenditures
for Commercial Fisheries
Expenditures
1986 $$$
(millions)
2
1.6
1.2
0.8
0.4
0
1967
1971
1975
1979
1983
1987
Year
Estimated Expenditures
Trend
78.3 Thousand per Year Average Increase

Figure 2



Ln (R/E) versus Escapement
Ugashik
Rho = -0.702
Nushagak
Rho = -0.718
Egegik
Rho = -0.758
Naknek
Rho = -0.627
Ln (R/S)
Escapement (millions)

Figure 3



Egegik River
Return
Escapement
10000
8000
6000
4000
2000
0
400
800
1200
1600
2000
Observed, 1974-81 BY
Observed, 1956-73 BY
Predicted
Replacement

Figure 4

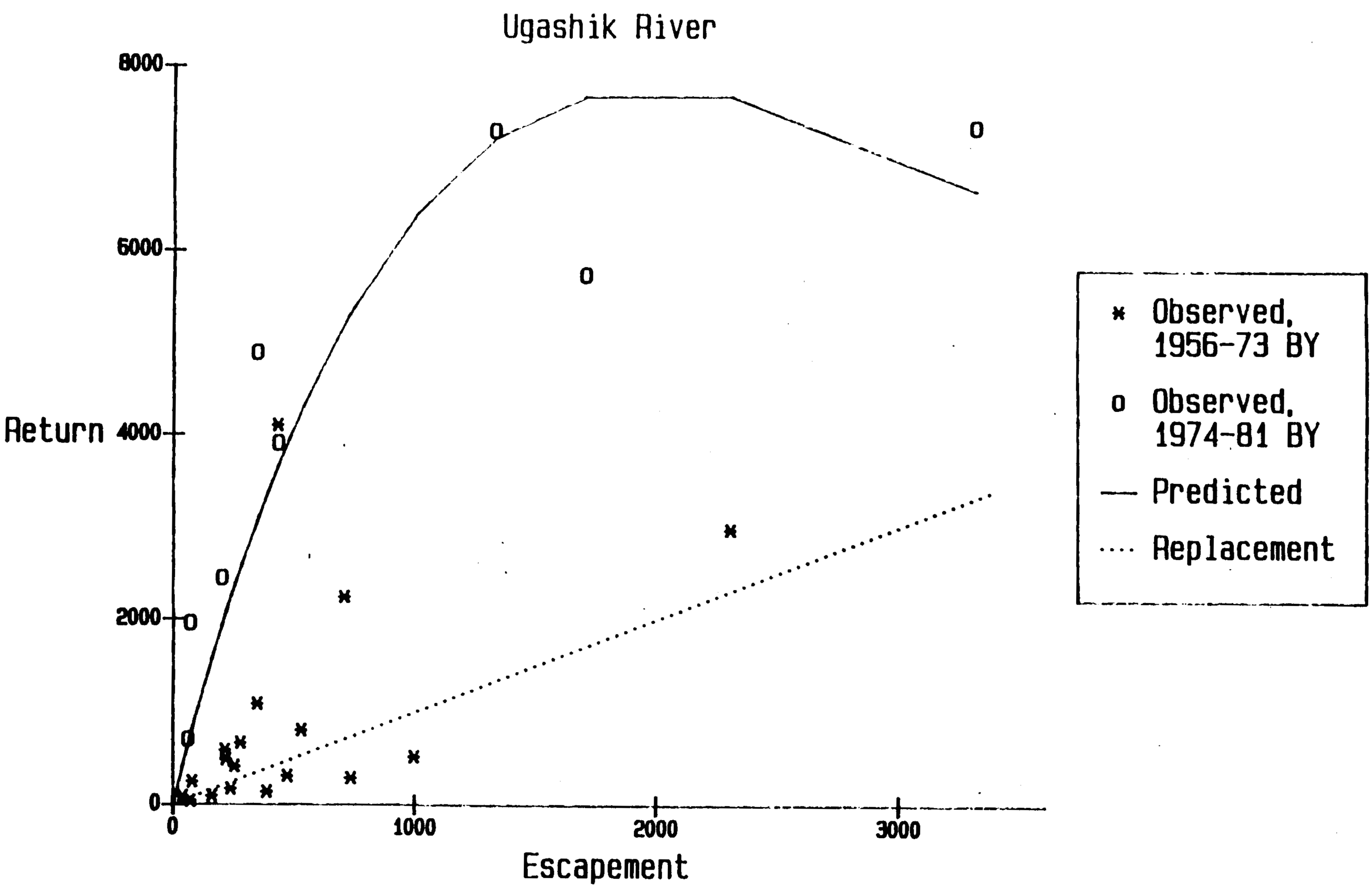
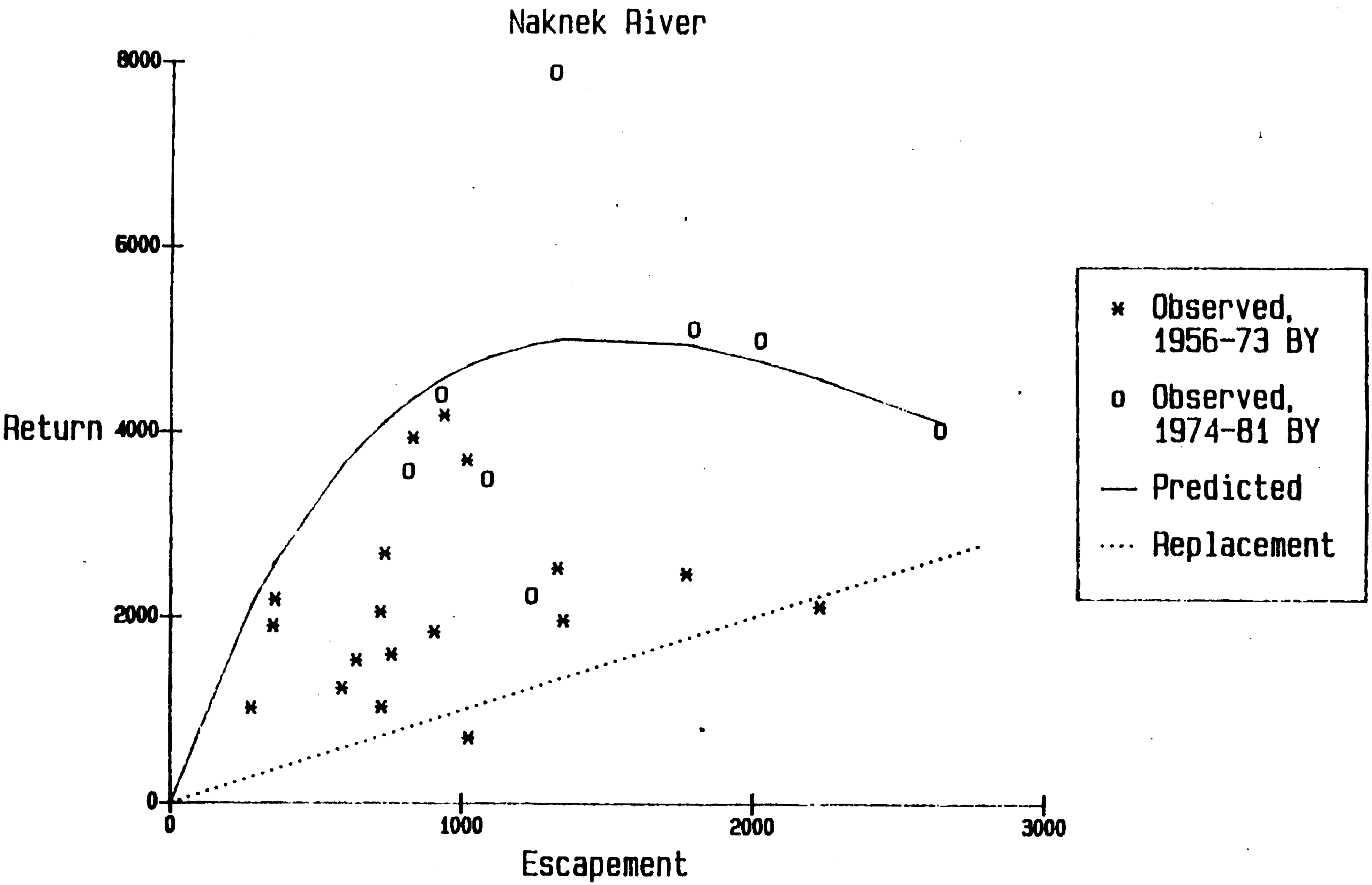
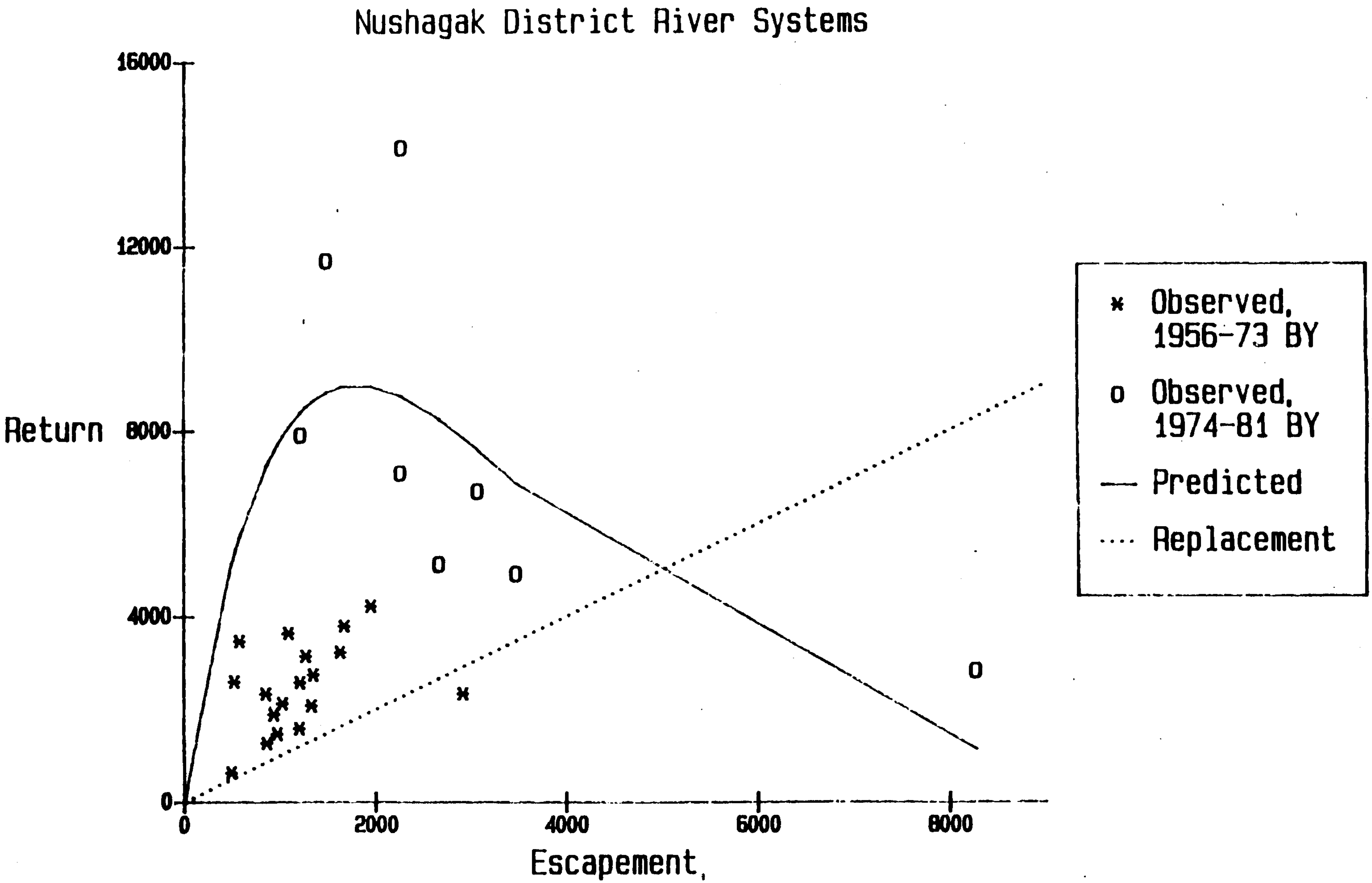

Ugashik River
8000
6000
4000
2000
0
Return
0
1000
2000
3000
Escapement
Observed, 1956-73 BY
Observed, 1974-81 BY
Predicted
Replacement

Figure 5



Naknek River
Return
8000
6000
4000
2000
0
0
1000
2000
3000
Escapement
Observed, 1956-73 BY
Observed, 1974-81 BY
Predicted
Replacement

Figure 6



Nushagak District River Systems
16000
12000
Return
8000
4000
0
0
2000
4000
6000
8000
Escapement,
Observed, 1956-73 BY
Observed, 1974-81 BY
Predicted
Replacement

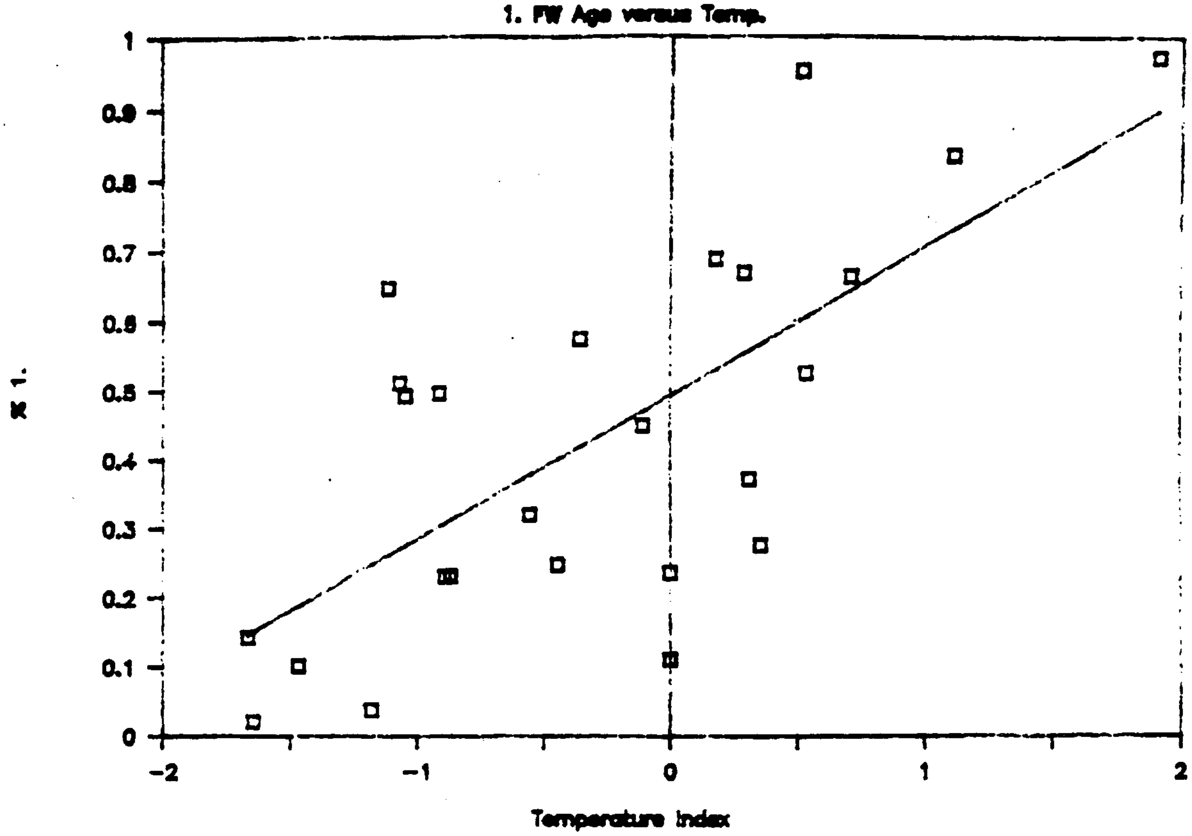
Figure 7.

Table 1. Parameters in the Ricker spawner recruit submodels estimated for each of the Bristol Bay sockeye stocks. Note that 1974 - 1981 escapement return data was used.

System	Equilibrium Escapement (thousands)	Initial Return per Spawner	Optimal Escapement (thousands)	Mean Residual Ln(R/S)	Std. Dev. Residual Ln(R/S)
Ugashik	4700	10.6	1576	0.194	0.4
Egegik	2800	15.7	865	-0.065	0.4
Naknek	3300	9.2	1139	-0.103	0.359
Nushagak	4700	13.6	1495	0.057	0.465

Figure 8

Ugashik River Sockeye



Nushagak District Sockeye

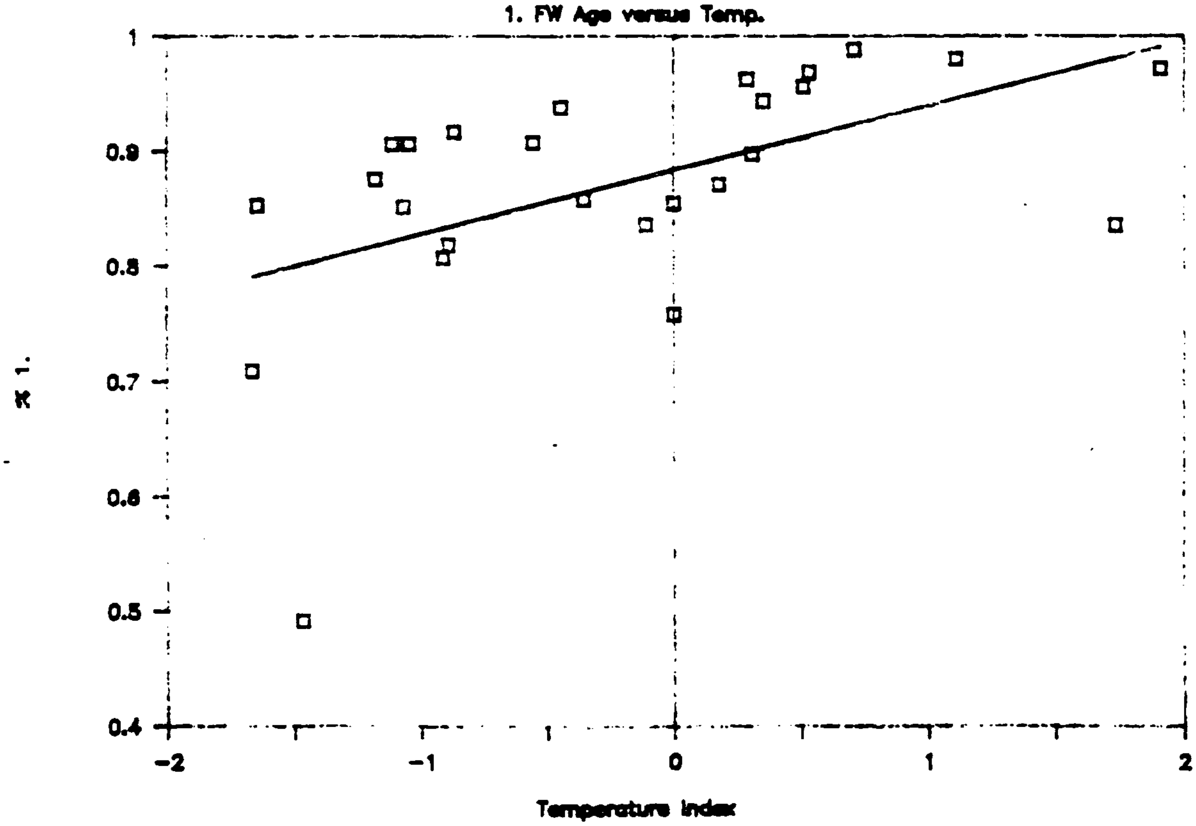
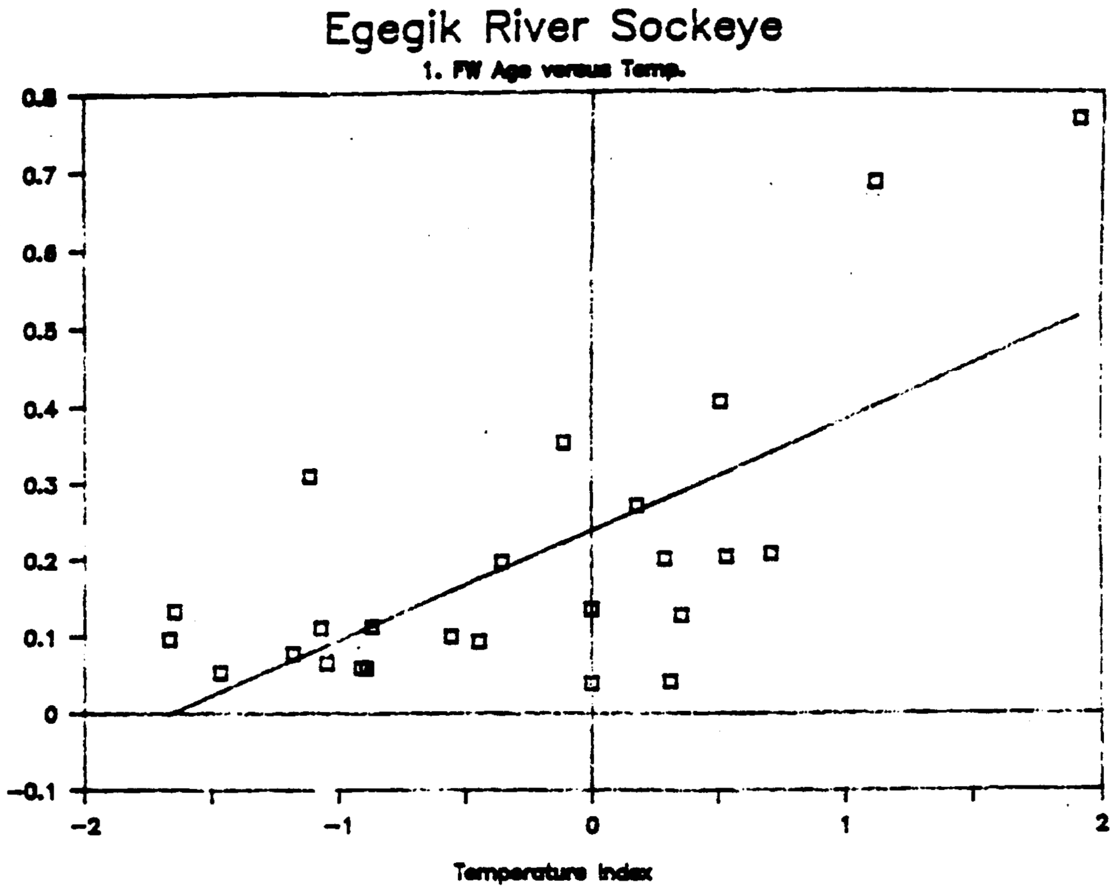
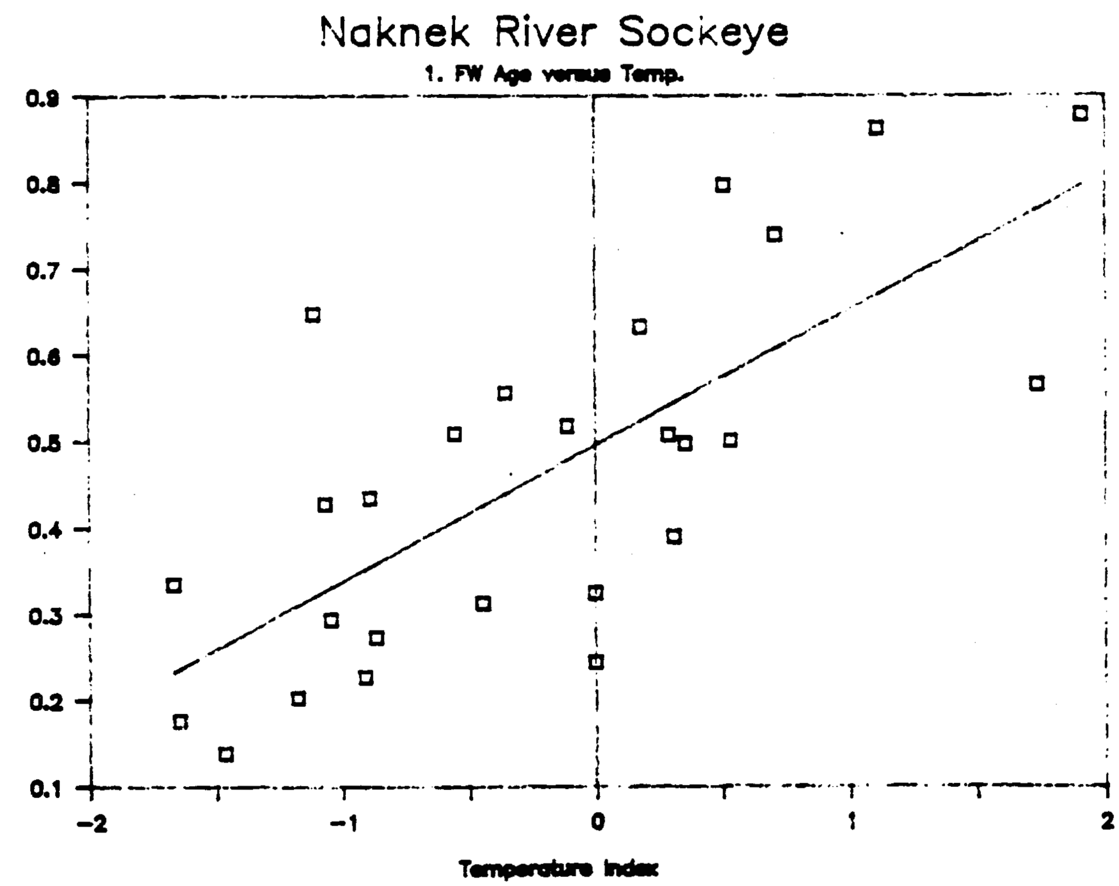


Figure 9

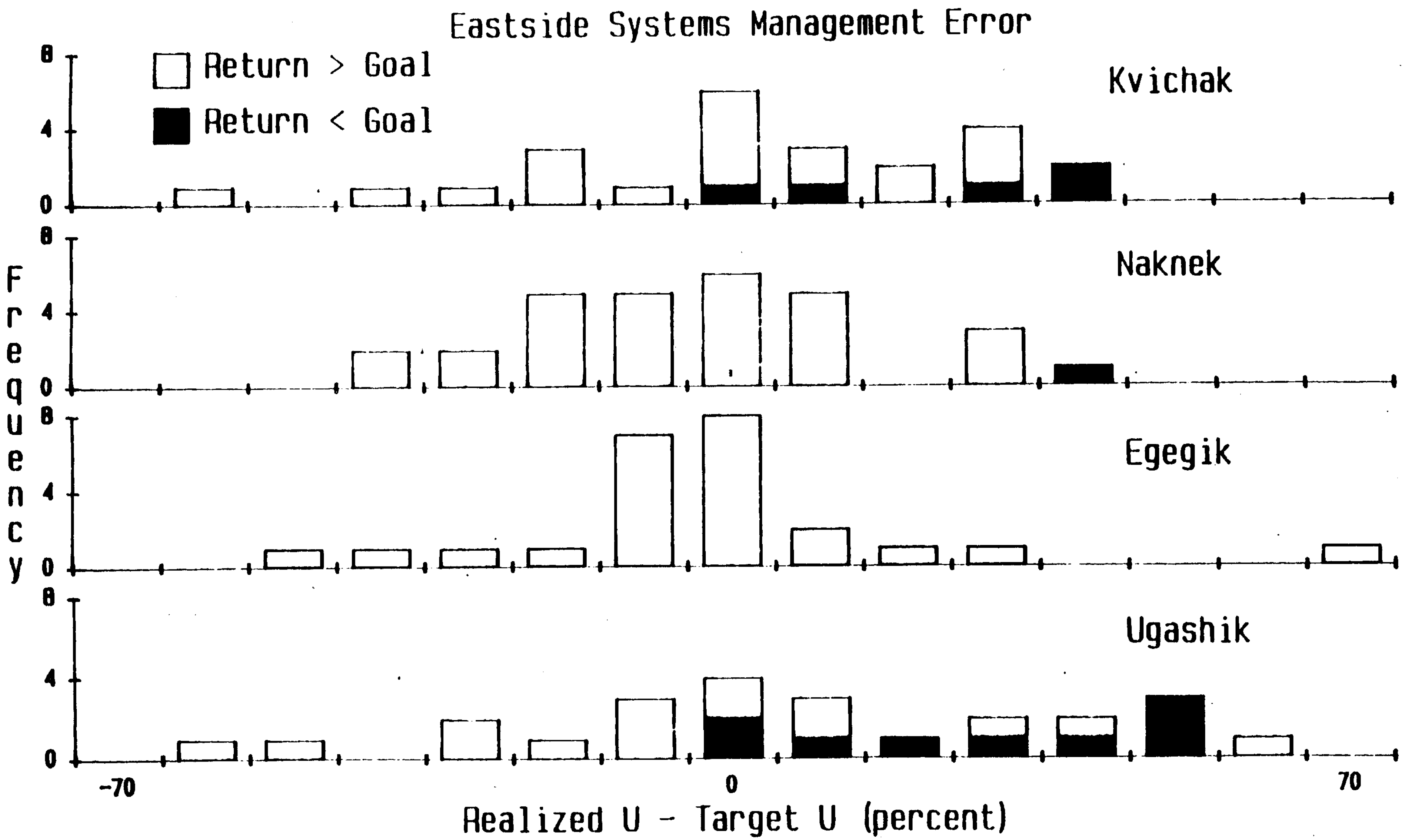


Egegik River Sockeye
1. FW Age versus Temp.
% 1.
Temperature Index



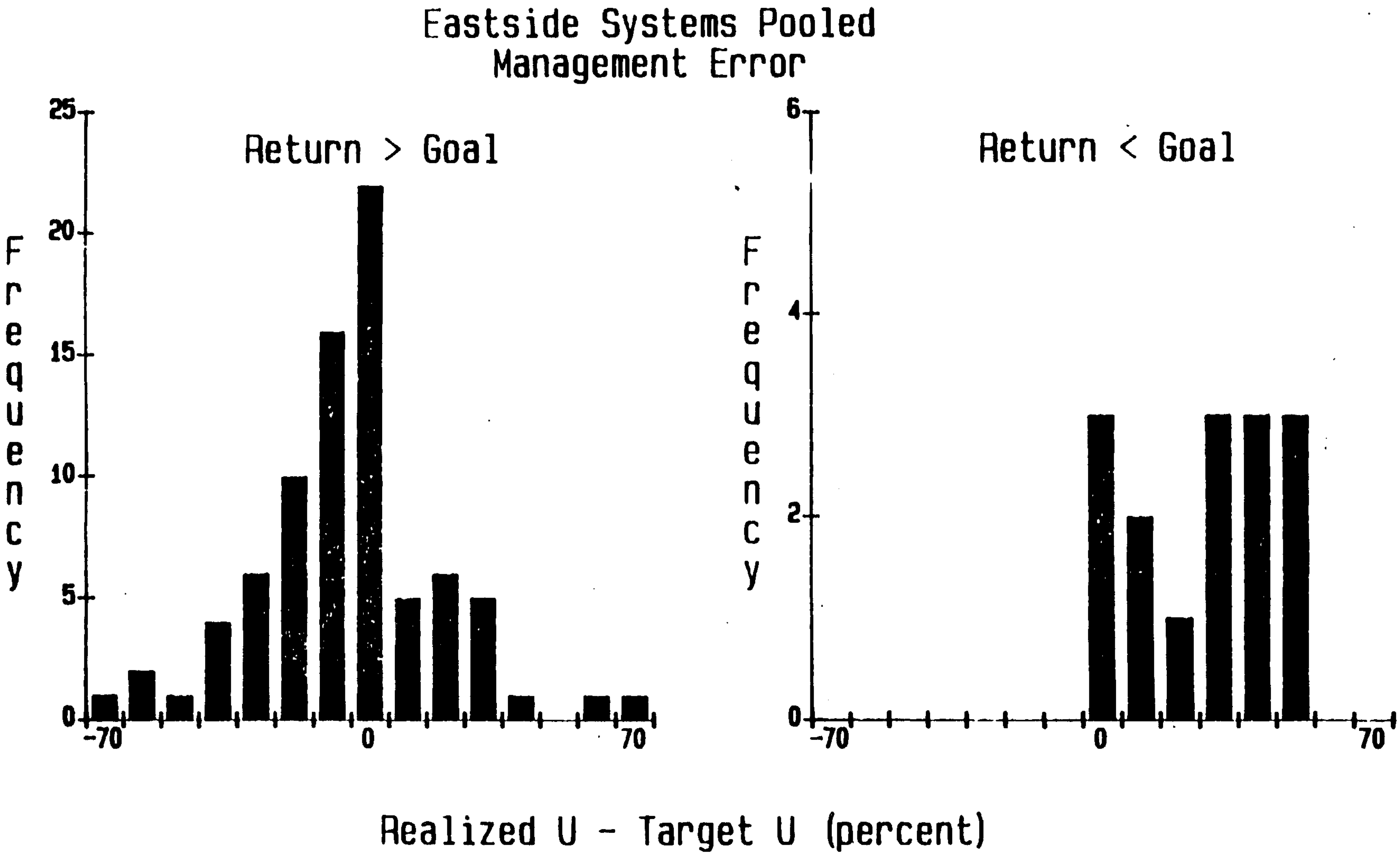
Naknek River Sockeye
1. FW Age versus Temp.
% 1.
Temperature Index

Figure 10



Eastside Systems Management Error
Return > Goal
Return < Goal
Kvichak
Naknek
Egegik
Ugashik
Frequency
0
4
8
-70
0
70
Realized U - Target U (percent)

Figure 11



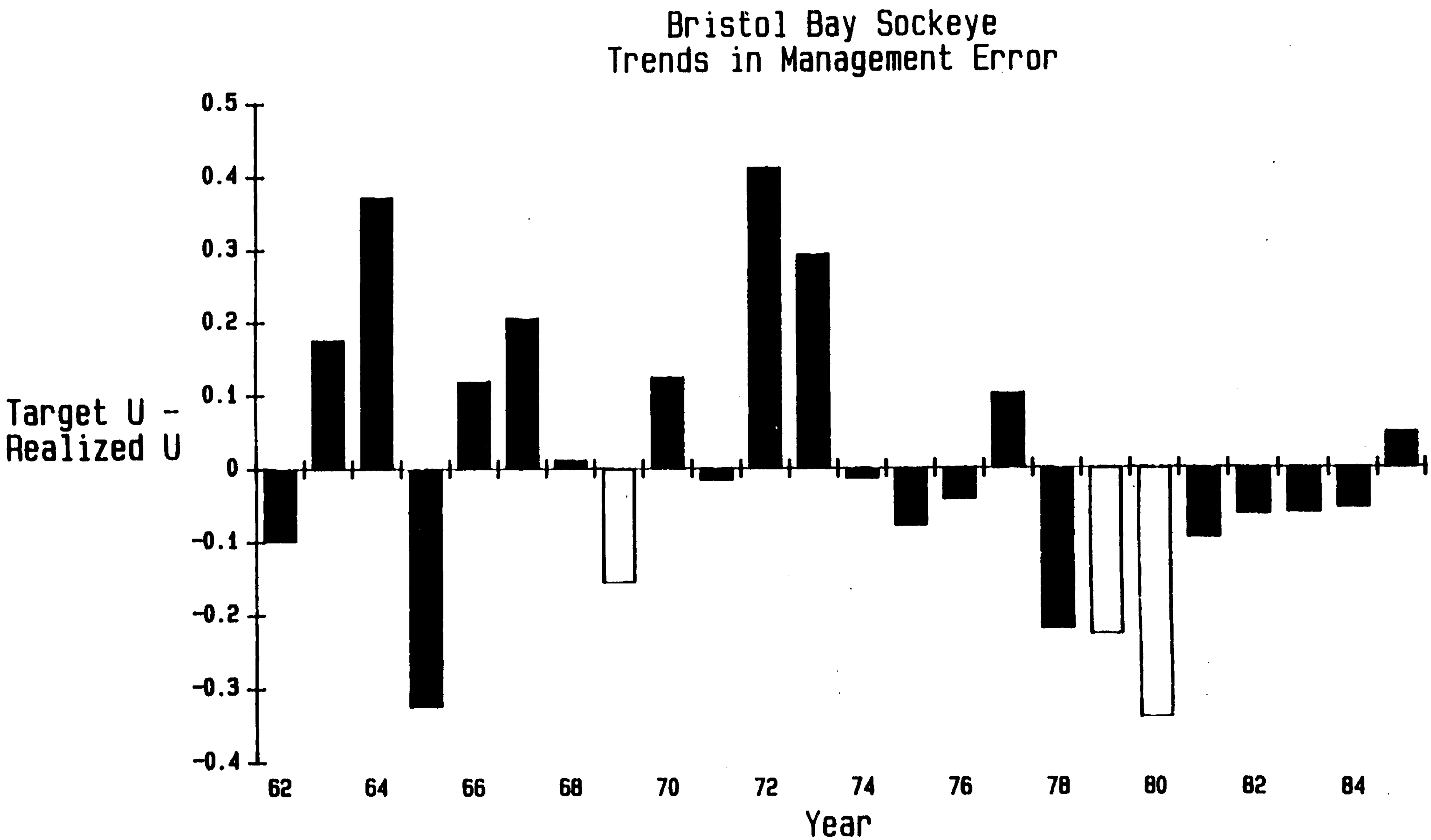
Eastside Systems Pooled
Management Error
Return > Goal
Return < Goal
Frequency
25
20
15
10
5
0
6
4
2
-70
0
70
Realized U - Target U (percent)

Table 2. Historical narrative of changes in Bristol Bay Management Policy, Regulatory regulatory actions, program elements, management precision, and level of funding

Year Policy Enacted	Policy	Regulatory Actions	Program Elements	Level of Management Precision (% Absolute Error)	Level of Funding 86 $$ (millions)
Before Statehood	White Act, 50% rate of exploitation	Fixed fishing times	Mimimal	>25 %	minimal
1960	Fixed escapement goals goals preliminary	Time Area Closures by emergency order	Local Management Catch and escapement enumeration Catch and escapement sampling Inseason Aerial Surveys	25%	0.2 *
1965	Formal escapement goals (millions) Kvichak, cyclic goals a 14 peak, 6 pre-peak, 2 off-peak Ugashik (.5), Egegik (.6), Naknek (.8) Wood (.8), Nuyakuk (.25), Igushik (.15)	Time Area Closures by emergency order	Local Management Catch and escapement enumeration Catch and escapement sampling Inseason Aerial Surveys Formal preseason forecast	21%	0.5 *
1984	Formal escapement goals (millions) Kvichak, review cyclic goals policy preliminary increase in off-peak and decrease peak goal Ugashik (.7), Egegik (1), Naknek (1) Wood (1), Nuyakuk (.5), Igushik (.2)	Time Area Closures by emergency order	Local Management Catch and escapement enumeration Catch and escapement sampling Formal preseason forecast Inside and offshore testfishing Smolt enumeration Inseason Aerial Surveys	7%	1.88
Unknown implementation requires additional funding	Formal escapement goals (millions) Kvichak, Alternating pre-peak and peak goals conditioned on year ahead forecast Ugashik increase Egegik (1), Naknek (1) Wood (1), Nuyakuk (.5), Igushik (.2)	Time Area Closures by emergency order Naknek special harvest area	Local Management Catch and escapement enumeration Catch and escapement sampling Formal more accurate forecasts Inside and offshore testfishing Smolt enumeration Inseason Stock Identification Inseason Aerial Surveys	<7%	2

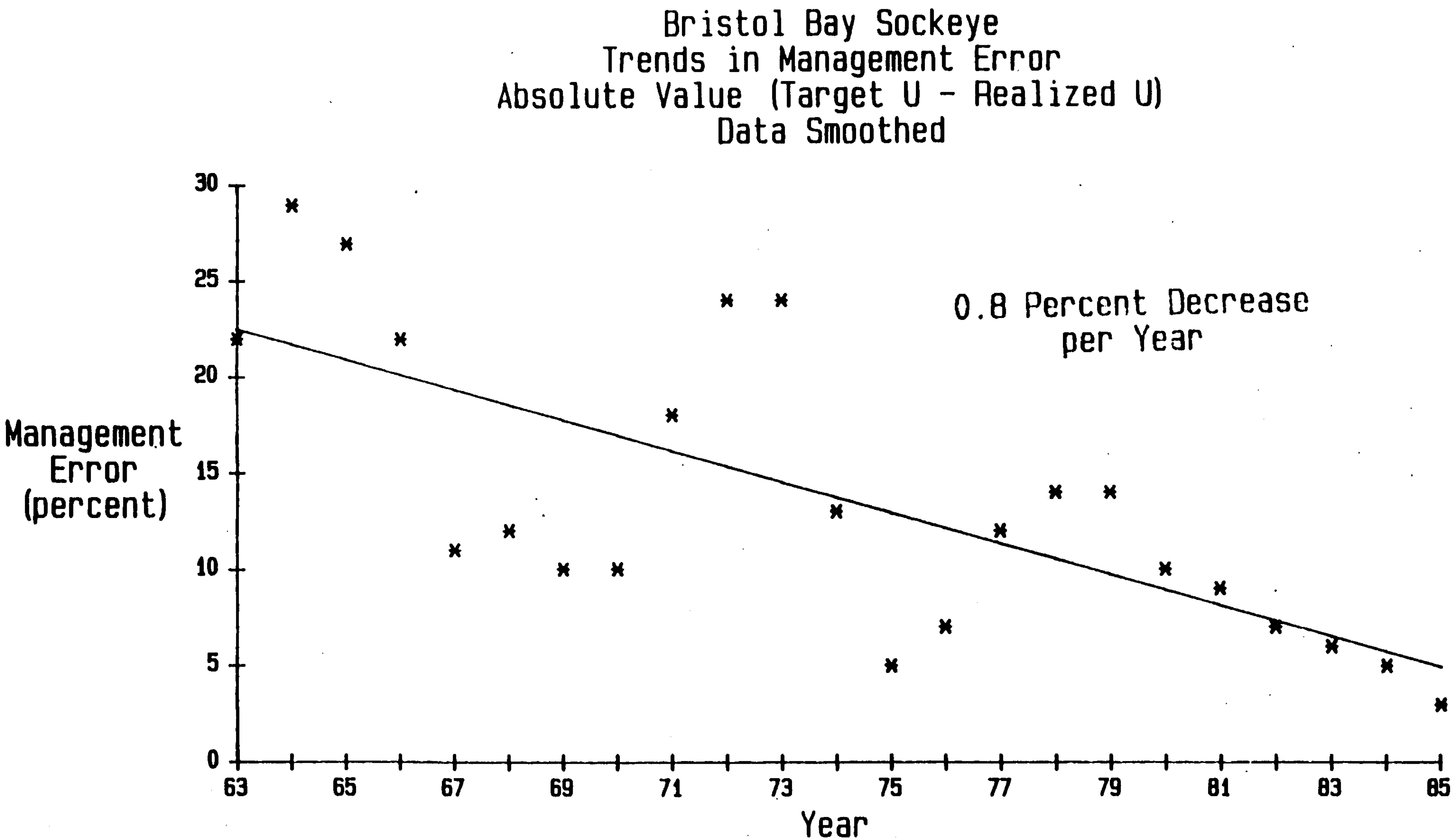
* very rough estimate

Figure 12



Bristol Bay Sockeye
Trends in Management Error
Target U - Realized U
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
62
64
66
68
70
72
74
76
78
80
82
84
Year

Figure 13



Bristol Bay Sockeye
Trends in Management Error
Absolute Value (Target U - Realized U)
Data Smoothed
0.8 Percent Decrease per Year
Management Error (percent)
Year
30
25
20
15
10
5
0
63
65
67
69
71
73
75
77
79
81
83
85

Figure 14.

Average Catch Expected Under
Alternative Management Policies
and Levels of Management Precision

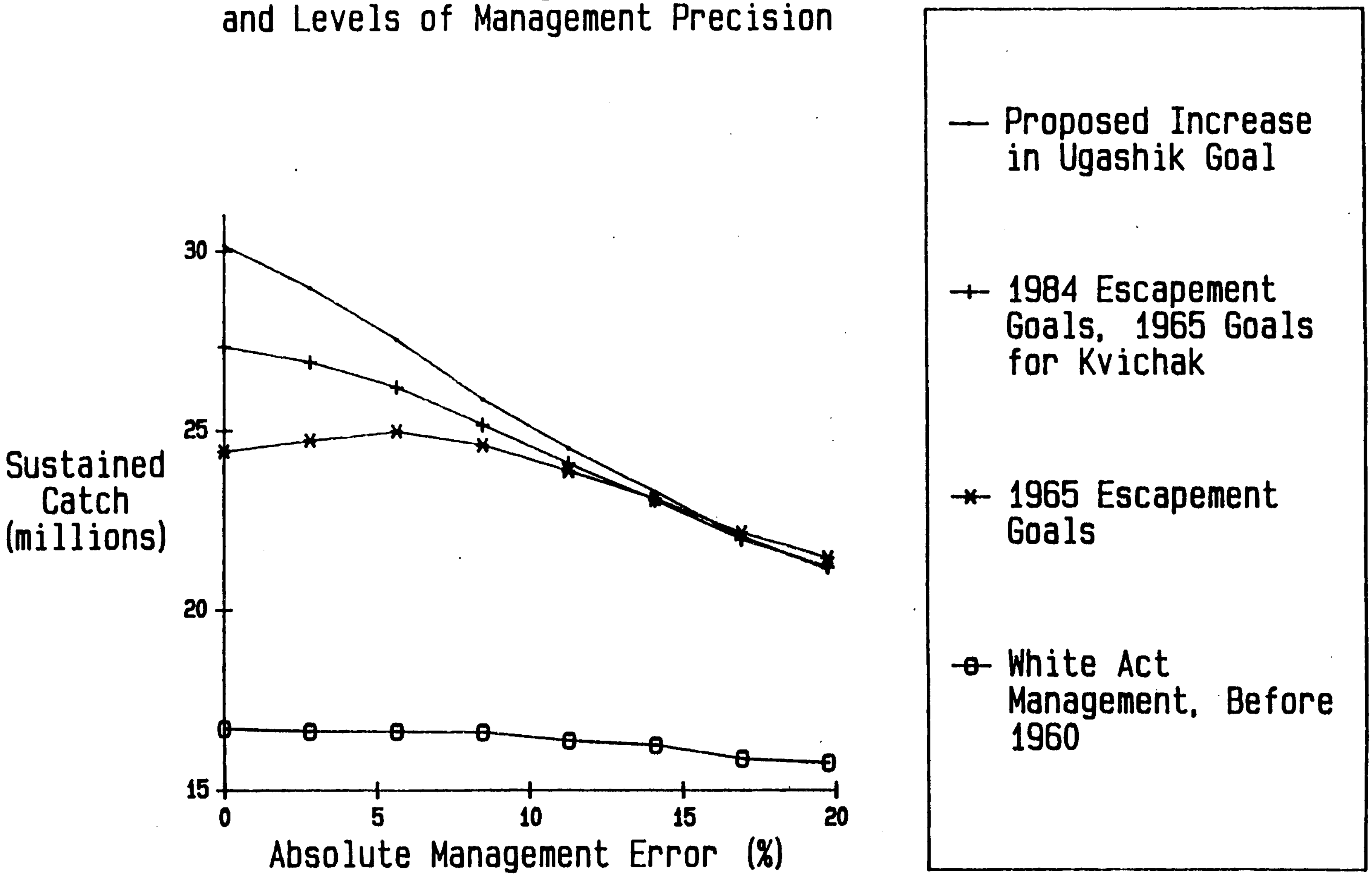


Table 3. Results of analysis of cost and benefits of the Div. of Commercial Fisheries Program in Bristol Bay. Note that Ex-vessel value assumed to be $6/fish.

Harvest Policy	Year of Policy Change	Level of Management Precision (% Absolute error)	Expected Harvest fish/year (millions)	Cost of Bristol Bay Program $$$/year (millions)	Marginal Benefit From Policy Change fish/year (millions)	Marginal Benefit From Policy Change Ex-Vessel $$$/year (millions)	Marginal Benefit From 1 % Reduction in Management Error fish/year (millions)	Marginal Benefit From 1 % Reduction in Management Error Ex-Vessel $$$/year (millions)	Benefits/ Costs for addional funding assume costs of 1% reduction is 98 thousand dollars ($$$'s)
White Act	1960	25%	9.7	???					
1965 Escapement Goals	1965	21%	21.4	$0.5	11.7	$70.2	0.288	1.72	18
1984 Escapement Goals	1984	7%	25.7	$1.8	4.3	$25.8	0.372	2.23	23
1987 Escapement Goals	1987	7% at FY 85 Funding	26.7	???	1	$6.0	0.59	3.54	36

FY88 Funding Options	Level of Management Precision (% Absolute error)	Expected Annual Harvest fish/year (millions)	Expected Annual Harvest $$$/year (millions)	Cost of Bristol Bay Program $$$/year (millions)	Ratio of Change in Ex-Vessel to Change in BB Expenditures
1 FY85 Funding with 1984 Policy	7%	25.6	$153.6	1.88	$0
2 Gov's FY88 Request with 1984 Policy	12%	23.3	$139.8	1.42	($30)

ABUNDANCE AND DISTRIBUTION OF JUVENILE SOCKEYE SALMON IN THE LOWER TAKU RIVER, ALASKA

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INTRODUCTION

The Taku River is an important producer of Pacific salmon (*Oncorhynchus* spp.) for both U.S. and Canadian fisheries. Sockeye salmon (*O. nerka*) are the most valuable species harvested in the Taku River. Abundance of returning adults has been well documented (Clark et al. 1986), but little information exists on the distribution and abundance of juveniles. Because the Taku River is a transboundary river, with headwaters in Canada and mouth in Southeast Alaska, information is needed on habitat availability and use so that salmon stocks can be jointly managed for optimum escapement and equitable harvest by the U.S. and Canada.

Most of the Taku River basin is in Canada, but the U.S. portion of the river, including numerous sloughs and beaver ponds, appears to offer extensive rearing habitat for juvenile salmon. Little is known of the salmon populations that rear in the U.S. part of the river or of their contribution to production from the river. The purpose of this study was to assess abundance, distribution, age, growth, and contribution to total salmon production of juvenile sockeye salmon in the U.S. part of the Taku River.

METHODS

A stratified random sampling design was used to estimate the abundance of juvenile sockeye, chinook (*O. tshawytscha*), and coho salmon (*O. kisutch*) in the lower Taku River, including off-channel sloughs, beaver ponds, and tributaries on the river terrace (Fig. 1). To stratify habitat, we combined and modified the systems of Sedell et al. (1983), Schmidt (1986), and Edgington and Lynch (unpublished manuscript). Habitat in the study area was divided into two broad categories: 1) river-channel habitats located within the active river channel and carrying river water, 2) and off-channel habitats on the river terrace fed from springs or from tributaries draining valley side slopes. Each broad category was subdivided according to water velocity regime and fluvial process, for a total of five river-channel habitats--main and side channels, channel edges, braids, side sloughs, and backwaters--and four off-channel habitats--tributaries, tributary mouths, upland sloughs, and beaver ponds. A total of 49 sites (3-10 of each habitat type), located from Taku Point to the Canadian border, were sampled once from 8 July to 18 September 1986.

At each site, 3-11 separate areas, spaced at least 50 m apart, were seined for fish. Main and side channels could not be seined because of swift, turbulent flow. Based on their current velocity, we assumed they did not support rearing salmon. All fish from each seine haul were anesthetized with MS-222, identified to species, and counted, and a sample was measured for fork length (FL) and aged by scales. Number of fish at each seined area was estimated by the removal method with at least three passes (Zippin 1958). Density was calculated by dividing the population estimate by the area seined, and density at each site was computed as the mean of the seined areas. Water velocity was measured by a current meter at each area, and the range of suitable water velocity for each salmon species was determined from probability-of-use curves (Bovee and Cochnauer 1977).

Downstream migrants were sampled with a stationary net set overnight near the Taku Lodge (19 km downstream of the U.S.-Canada border) about once a week from 6 August to 19 September. The net was 3 m wide by 1.5 m deep at the entrance and funneled to a cod end of 6-mm mesh. Placed about 4 m from shore, the net was secured to a dock so that it rested on the bottom of the main channel, perpendicular to the flow.

Total populations of juvenile salmon in the U.S. part of the river were estimated from total area and mean fish density of the habitat types (Cochran 1953). Total area of each habitat type was measured by digitizing outlines of habitats drawn on aerial photographs (scale, 1:6,621).

RESULTS

Salmon Abundance, Distribution, Age, and Size

Juvenile sockeye salmon primarily used habitat with slow or standing water. Based on the probability-of-use curve, optimum water velocity for sockeye salmon was about 0 cm/s, and habitats with velocity greater than 28 cm/s were unused (Fig. 2). Based on this curve, water velocity in all habitat types, except main and side channels, was suitable for juvenile sockeye salmon. Sloughs, backwaters, and beaver ponds were optimal, whereas channel edges, braids, and terrace tributaries generally were suboptimal but still suitable for sockeye salmon. Main and side channels, except their edges, were unsuitable because their swift (30-75 cm/s) currents were well above the usable range. Sockeye salmon preferred current velocities similar to those preferred by coho salmon but differed significantly ($\underline{P}$ = 0.001; Kolmogorov-Smirnov test) from chinook salmon which used currents between 2 and 20 cm/s more frequently than did the other species.

Sockeye salmon was the most abundant species in the U.S. part of the river (Table 1, Fig. 3). Average density in the river and off-channel areas was $0.11/m^2$--about twice the average density of coho and chinook salmon. Sockeye salmon were most abundant in areas with standing water in both the river channel and off-channel terrace (side sloughs, backwaters, tributary mouths, upland sloughs, and beaver ponds). Sockeye salmon also were in habitats with moving water (channel edges, braids, and terrace tributaries), but at a much lower density. Sockeye salmon density, however, did not differ significantly ($P = 0.35$; Kruskal-Wallis test) between habitat types because of high variation, mainly caused by their absence from some upland sloughs and beaver ponds. For example, of four upland sloughs sampled, sockeye salmon were absent from one and common ($0.05\text{-}0.33/m^2$) in the other three. If only sites with sockeye salmon were included in the analysis, differences in density between habitat types were highly significant ($P = 0.009$; $n = 34$ sites; Kruskal-Wallis test).

Sockeye salmon ranged from 27 to 84 mm FL July-September, and frequency distributions of FL's each month closely approximated the normal distribution, indicating presence of only one age class. Nearly all of the 250 sockeye salmon whose ages were determined from scale samples were young-of-the-year; only one was age 1. Mean FL of sockeye salmon increased linearly, from about 40 mm FL in early July to 55 mm FL in late September, a growth of 0.24 mm per day. Most sites conformed well to the relationship between mean FL and date; however, two beaver ponds were significant ($P < 0.01$; t-test) outliers, with much larger salmon than expected for that date. The warmer water in beaver ponds probably encouraged faster growth than in the other habitats.

Juvenile sockeye salmon in the lower Taku River are unusual in that they rear in riverine habitat, whereas most other sockeye salmon populations typically rear in lakes. Juvenile sockeye salmon are known to rear in other large rivers, however, including the Stikine, Copper, and Susitna rivers in Alaska and the Bolshaya and Kamchatka rivers in Kamchatka (Foerster 1968; Lake 1984; Craig 1985; Schmidt 1986; Edgington and Lynch, unpublished manuscript). As in the Taku River, juvenile sockeye salmon in the Stikine River rear in both the river-channel and off-channel habitats, feeding mainly on Chironomidae (Lake 1984). Thus, large rivers can provide important rearing habitat for juvenile sockeye salmon.

Downstream Movement

In the six nights fished, the migrant trap caught 592 salmon, of which most (99%) were juvenile sockeye and coho salmon (Fig. 3). Chinook salmon were rare. Catch was low in the first half of August, increased sharply in late August, and declined to a low level again in September (Fig. 4).

Catch was not closely related to river stage, but appeared to relate better to a combination of river stage and precipitation. Generally, river flow gradually declined during August and September, except for two discharge spikes: a sharp spike during 12-16 August when the Tulsequah River ice dam burst, swelling the river to >70% its previous stage; and a much smaller spike during 28-30 August when heavy rains raised the river about 30% (Fig. 4). The second spike, however, was still lower than the average flow in early August. The source of the downstream migrants probably was the river terrace rather than the river channel. Sockeye salmon were abundant in off-channel habitats and in the migrant trap. Furthermore, catch of migrants stayed low when the Tulsequah flood swept the river channel while off-channel habitats were unaffected, but catch increased sharply when heavy rains flooded river-channel and off-channel habitats.

Sockeye salmon were about 28% of the salmon catch. They ranged from 39 to 72 mm FL, similar to their mean size in the rearing habitats, and all sampled fish were fry. Many had the silvery appearance of presmolts indicating that some downstream migrants may have gone to sea. Numerous sockeye salmon were caught in sites downstream of the trap site; thus, the migrants could have been moving to the lower river to rear.

Many adult sockeye salmon returning to the Taku River lacked a freshwater annulus on their scales and appeared to have gone to sea as young-of-the-year. About 40% of returning adults that spawned in the mainstem Taku River had no freshwater annulus (Eiler, Auke Bay Laboratory, unpublished data). Taku River stocks that spawn in river sections generally have more salmon without a freshwater annulus than do stocks that spawn in the lakes (McPherson and McGregor 1986; Eiler unpublished data). Thus, the downstream migrants probably return as adults to contribute to catch and escapement.

Sockeye salmon adults in other rivers may have a life history similar to those in the lower Taku River. The Stikine River near Wrangell, Alaska, also has adult sockeye salmon returns from juveniles that went to sea as young-of-the-year (McPherson and McGregor 1986), and almost all adult sockeye salmon from the East River near Yakutat, Alaska show no freshwater annulus (McBride and Brogle 1983). A similar life history was noted by Foerster (1968) for sockeye salmon in the Paratunka River, Kamchatka, where young-of-the-year rear in the river less than a year but sometimes for several months. Other large rivers (Kamchatka River; Harrison River, British Columbia) also have the "ocean-type" sockeye salmon (Foerster 1968) that migrate to sea as soon as they are free-swimming. In the Taku River, the downstream migration of juvenile sockeye salmon past the U.S.-Canadian border has two modes: a peak migration in May-June and a protracted, reduced migration in July-October (Meehan and Vania 1960). The first mode probably consists of age 1 and older smolts and possibly "ocean-type" fry, whereas the second mode consists mostly of young-of-the-year sockeye salmon that have reared in the river for several months. Many of these migrants, however, may overwinter in the lower river rather than go immediately to sea.

Total Populations

Total area of the U.S. part of the Taku River, including off-channel habitats on the river terrace, from Taku Point to the Canadian border was 1,932 ha, as calculated from aerial photographs

(Table 1). This area does not include Twin Glacier Lake, Wright River, Wright Lake, Sittakanay River, and the portions of tributary streams beyond the river terrace. Most (69%) of the area was composed of main and side channels, where swift current precluded rearing. Channel edges, the only suitable rearing area in these channels, made up only 2% of total area. Almost a quarter of the area consisted of braids. Side sloughs and backwaters made up only 2%, and off-channel habitats only 5% of total area.

The total number of salmon in each habitat type was a function of the habitat's total area and mean salmon density (Table 1). Because of the large area of braids, the greatest number of sockeye salmon were in this habitat (35%), even though mean density there was low. The most important habitats, however, represented only a small portion of the total area in the lower river. Despite their small area (3% of total), beaver ponds and sloughs together accounted for 38% of the sockeye salmon.

Estimated total population of juvenile sockeye salmon in the U.S. part of the river was 633,000 (Table 1). Because of the large variance in salmon density within habitat types, however, the total population estimate had a wide confidence interval. With 95% confidence, the true total populations ranged from 182,000 to 1,084,000 sockeye salmon. This estimate does not account for seasonal or annual variation.

The contribution that these fish make to the total salmon production from the river can be estimated from simple population models using mean parameters from the literature (Table 2). The 1985 escapement was 104,000 adults composed of 45% females (McPherson and McGregor 1986). With an assumed fecundity of 4,000 eggs per female (Foerster 1968), 94% egg deposition (Manzer and Miki 1985), and 10.6% egg-to-fry survival (Foerster 1968), the number of fry produced in 1986 was nearly 19 million. These fry probably suffered heavy mortality during their first few months. Major losses (65%) prevail during the first 2.5 months, June to August, after which losses rapidly decrease as the fry grow (Foerster 1968). Based on this 65% loss, about 6.5 million fry should have survived until August 1986. Thus, the estimated 633,000 juvenile sockeye salmon rearing in the U.S. part of the river in July to September represent about 10% of the estimated total number of juvenile sockeye salmon from the 1986 brood rearing in the Taku River system.

During the ensuing 8-month (from September to the May smolt migration, 75% of the sockeye salmon present in August can be expected to die (Foerster 1968). Hence, the yield from the whole river should be about 1.6 million smolts, and yield from the U.S. part about 160,000 smolts. Assuming 10% marine survival (Foerster 1968; Ricker 1976), the total adult return should be about 163,000, of which about 16,000 had reared in the U.S. part of the river. This estimate compares favorably with the estimated total return (composed of parts of four brood years) in 1985 of Taku River sockeye salmon 192,000 (104,000 escapement + 74,000 harvested by the Alaska District 111 fishery + 14,000 harvested by the Canadian in-river fishery) (McPherson and McGregor 1986). Of the 88,000 sockeye salmon harvested, about 9,000 (10%) probably reared in the U.S. part of the river.

Our estimates of total populations probably were conservative, and the contribution of the U.S. area to the river's salmon production could be higher. Mortality estimates from the literature may be inappropriate for the lower Taku River, where conditions are much different from the lakes. Based on analysis of scales from adults (McPherson and McGregor 1986), a third to one-half of the sockeye salmon from riverine areas probably go to sea as young-of-the-year without overwintering, whereas those from the lakes overwinter once or twice. Freshwater mortality of the river stocks could be lower than for the lake stocks; hence, the contribution to salmon production from the U.S part of the river could be higher than estimated.

The U.S. salmon stocks also could be underestimated because several areas in the U.S. part of the river basin--Twin Glacier Lake, Wright River and Lake, Sittakanay River, the intertidal basins of upper Taku Inlet, and tributary streams on the valley slopes--were not sampled but could provide rearing habitat. Sockeye salmon probably do not rear in the valley-wall sections of tributary streams because of the small size and steep gradient of the streams in those sections.

Twin Glacier Lake area (1,100 ha) equals more than half the total area of the river-channel and off-channel habitats in the U.S. part of the Taku River. We seined 1,600 m^2 of the 35 ha of littoral habitat in the lake, but caught only four sockeye salmon. Lack of spawning habitat in the lake and its tributaries probably limits salmon abundance in the lake, because juvenile salmon probably colonize the lake from the river. We did not sample the pelagic zone for fish. A hydroacoustic survey of the lake indicated a layer of potential forage for sockeye salmon (Krieger unpublished data). Plankton tows in the upper 25 m of water collected numerous cyclopoid copepods. Thus, the pelagic zone of Twin Glacier Lake is a potential rearing area for sockeye salmon.

Undoubtedly, some areas in the lower Taku River are underutilized because of low escapement or poor access and possibly could be enhanced. Because only a small part of the total area accounted for most of the rearing populations, full seeding of the available sloughs and beaver ponds is critical to maximize production from the Taku River. Because sockeye salmon populations in large glacial rivers have not been adequately studied, such basic information as salmon population dynamics and species interactions is lacking. More research is needed to define the factors that limit salmon production from the lower river before enhancement programs are developed.

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Table 1.--Area, fish density, and total population of juvenile sockeye salmon by habitat type in the lower Taku River, Alaska, in July-September 1986. Standard error of fish density is in parentheses; n = number of habitats sampled. Data on coho and chinook salmon are provided for comparison.

Habitat type	n	Area: ha	Area: %	Fish density (no./ha): Sockeye	Fish density (no./ha): Coho	Fish density (no./ha): Chinook	Total population (thousands): Sockeye	Total population (thousands): Coho	Total population (thousands): Chinook
RIVER-CHANNEL HABITATS									
Main and side channels	0	1,342	69.5	0 (0)	0 (0)	0 (0)	0	0	0
Wooded channel edge	7	29	1.5	901 (502)	159 (61)	1,796 (996)	26	5	52
Nonwooded channel edge	10	7	0.4	348 (133)	51 (27)	172 (61)	2	0	1
Braid	5	408	21.1	548 (412)	100 (76)	338 (162)	224	41	138
Side slough	5	36	1.9	3,582 (1,266)	118 (38)	646 (515)	129	4	23
Backwater	3	9	0.5	2,110 (1,416)	290 (256)	513 (257)	19	3	5
OFF-CHANNEL HABITATS									
Terrace tributary	7	52	2.7	173 (150)	1,150 (420)	668 (485)	9	60	35
Tributary mouth	4	29	1.5	3,789 (2,128)	2,274 (1,988)	643 (500)	110	66	19
Upland slough	4	7	0.4	7,343 (4,556)	5,823 (2,694)	0 (0)	51	41	0
Beaver pond	4	13	0.7	4,793 (3,973)	5,850 (2,757)	93 (92)	62	76	1
Totals	49	1,932	100.0				633	295	274
						95% confidence limits	182-1,084	122-468	90-458
						degrees of freedom	8	14	8

Table 2.--Computation of number of Taku River sockeye salmon at different life stages.

Life stage	Number (thousands)
Sockeye salmon escapement, 1985[a]	104
Adult females[a] (45% of escapement)	47
Number of eggs[b] (Assumed 4,000 eggs per female)	188,245
Egg retention [c] (6.5% of fecundity)	-12
Eggs deposited[c]	176,009
Post-emergent fry[b] (Assumed 10.6% egg-to-fry survival)	18,657
Summer residents[d] (Assumed 65% mortality from emergence to August)	6,530
Smolts[d] (Assumed 75% mortality August to May	1,632
Returning adults[b], [e] (Assumed 10% marine survival)	163
Harvest[a] (46% of run)	75
Escapement[a]	88

[a] McPherson and McGregor (1986).
[b] Foerster (1968).
[c] Manzer and Miki (1985).
[d] Foerster (1968).
[e] Ricker (1976).

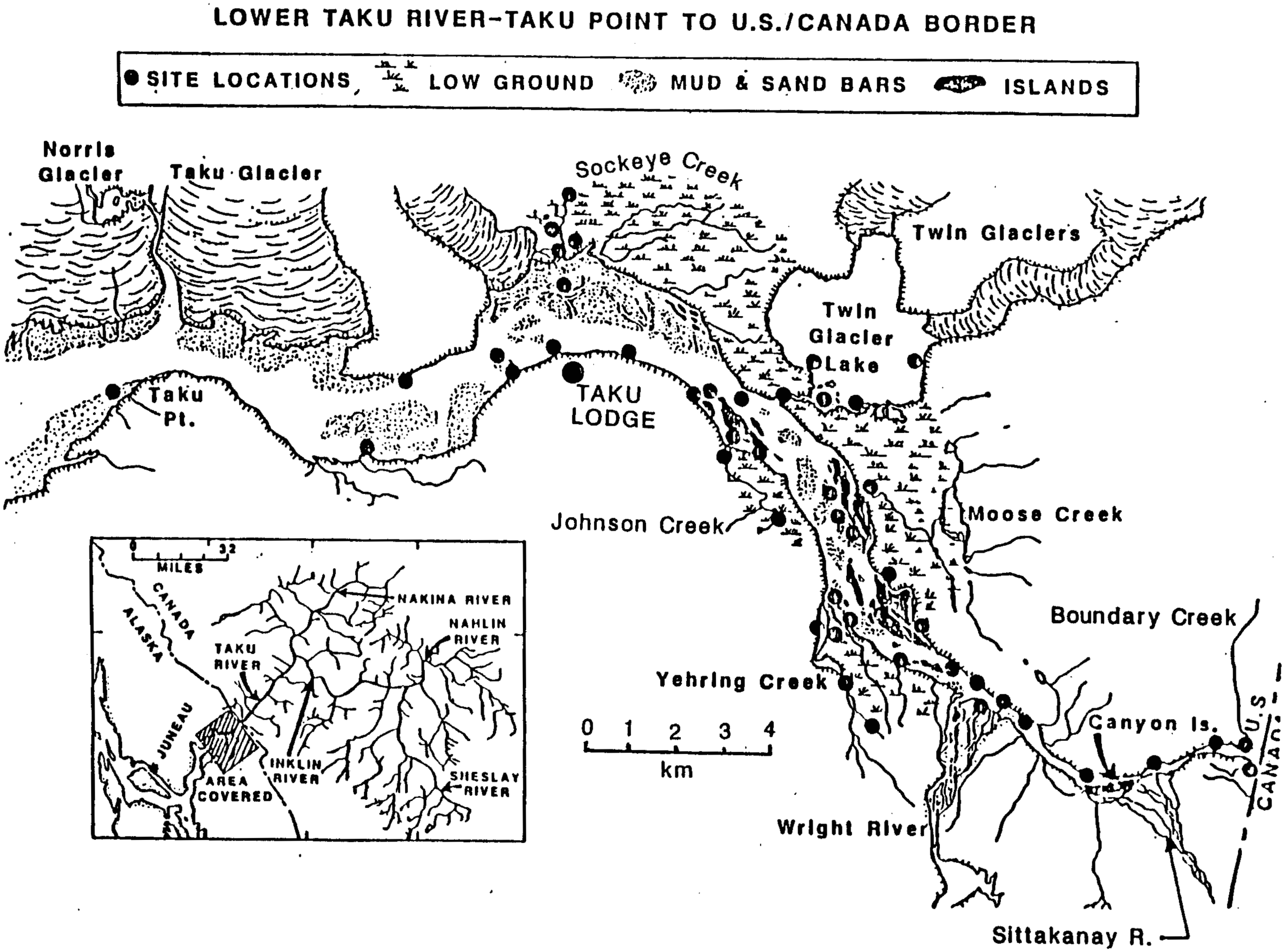

Figure 1.--Map of the study area, showing locations of sampling sites on the lower Taku River.

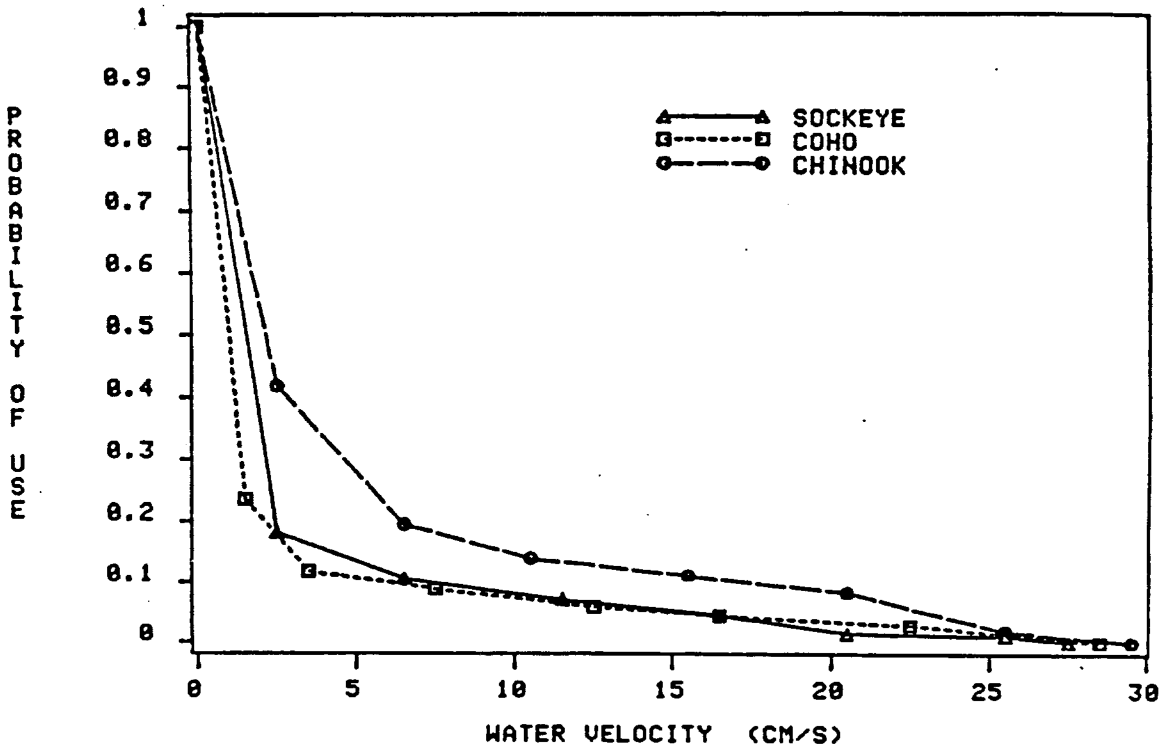

Figure 2.--Probability-of-use curves for juvenile salmon versus water velocity in the lower Taku River. The curves were constructed as described in the Methods.

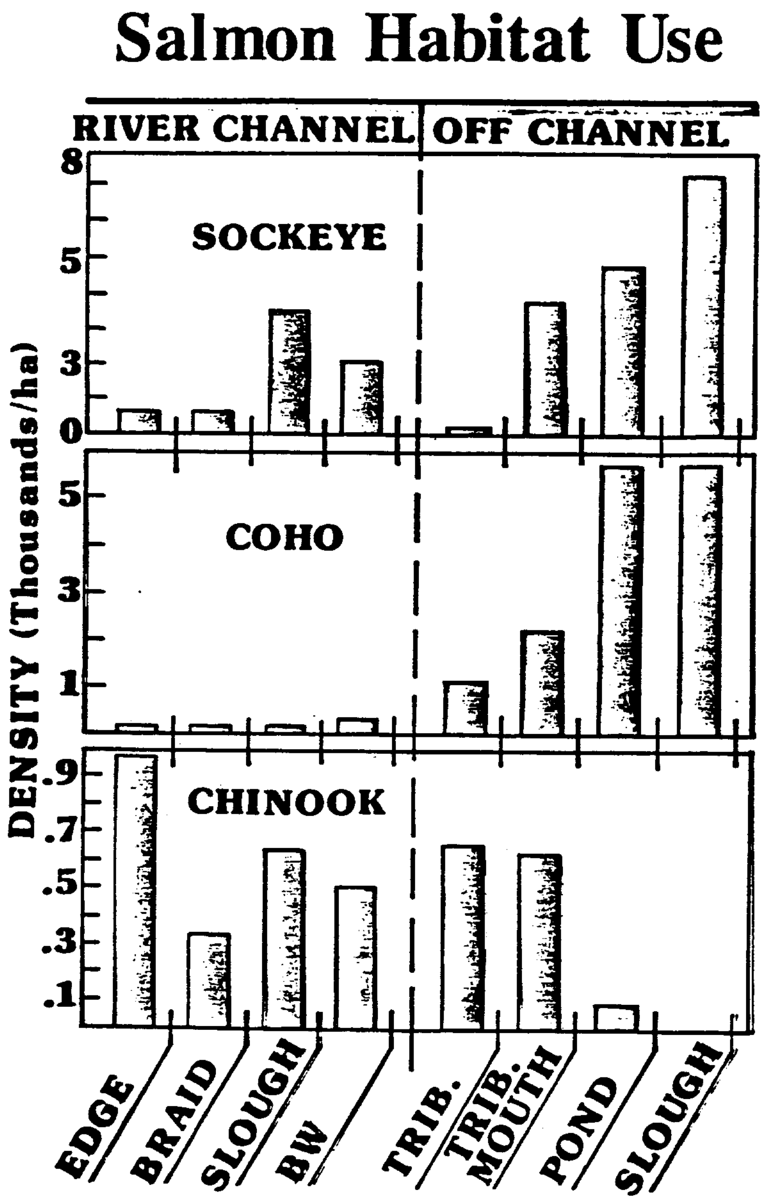

Figure 3.--Mean density of sockeye, coho, and chinook salmon by habitat type.

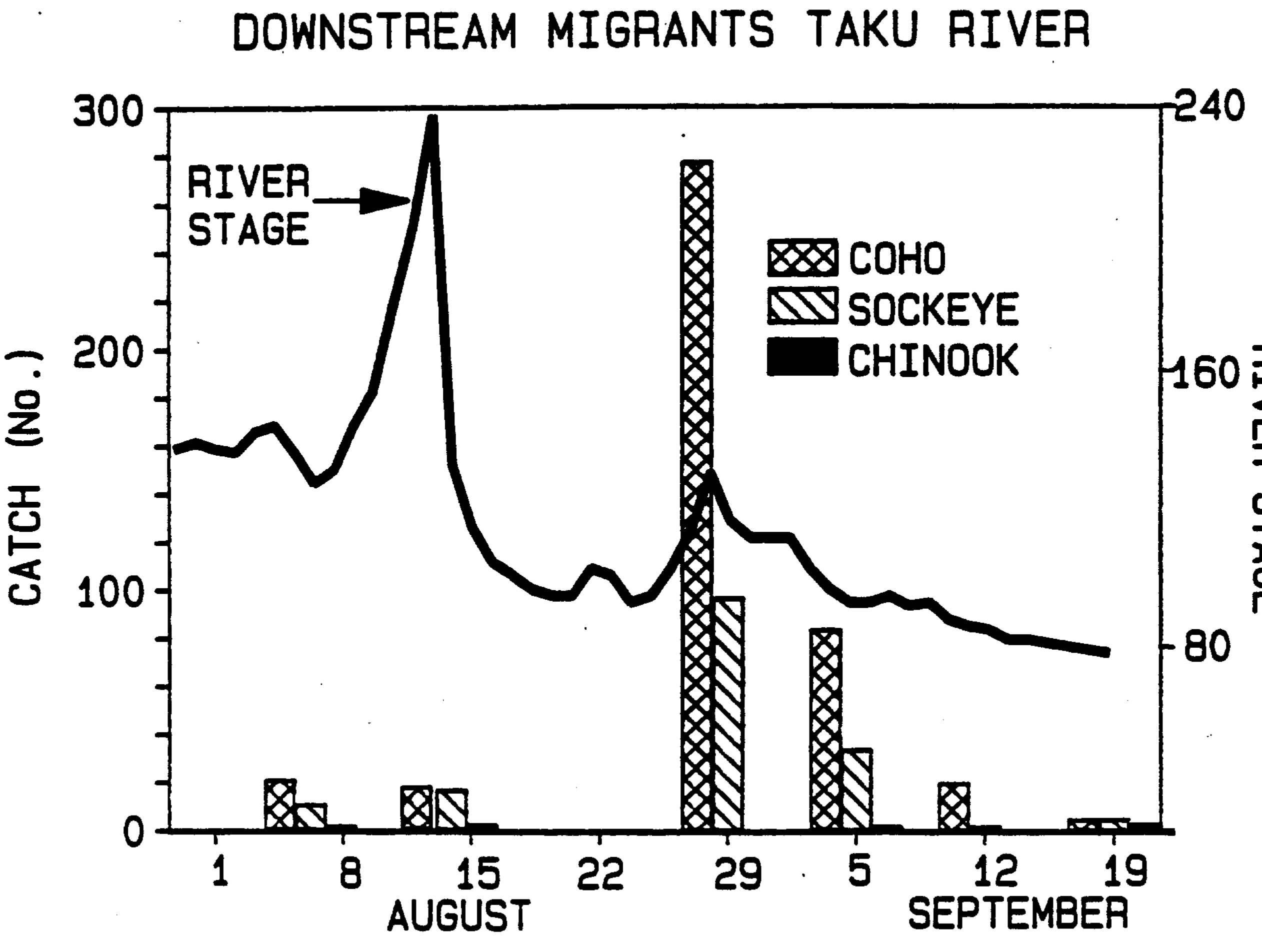

Figure 4.--Number of sockeye, coho, and chinook salmon caught in the downstream trap at the Taku Lodge site and river stage in August and September.

ADULT SOCKEYE SALMON DISTRIBUTION AND SPAWNING HABITAT UTILIZATION IN THE TAKU RIVER IN SOUTHEASTERN ALASKA AND NORTHWESTERN BRITISH COLUMBIA

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The Taku River is one of three rivers categorized by the Pacific Salmon Treaty as transboundary rivers which have their headwaters in Canada but flow through the United States. The Pacific salmon (Oncorhynchus spp.) resource of these rivers is important to both countries; management and research needs are specifically addressed by the Treaty. Basic information on escapement, in-river distribution, and habitat utilization is needed to manage the salmon in these rivers. In addition, the Treaty specifies that efforts will be made to enhance salmon runs on the transboundary rivers and that studies will be undertaken to determine the feasibility of enhancement and the potential impact on natural stocks.

Adult sockeye salmon (O. nerka) in the Taku River were studied in 1984 and 1986 with radio telemetry to obtain information on their in-river distribution and migration rates and the location and habitat characteristics of important spawning areas. Information of this type is difficult to obtain by conventional methods because of the large size of the river, limited access, and limited visibility of the water due to the glacial nature of the river; therefore, radio telemetry (locating fish tagged with small radio transmitters) was used. Baseline stock separation samples for sockeye salmon were also collected from the main stem of the river.

In 1984 and 1986, adult salmon moving upstream were captured by fish wheels in the lower river (just above saltwater influence and 4 km below the U.S./Canada border). Sockeye salmon were tagged with radio transmitters placed in the stomach, and were located at least once a week by boat or fixed-wing aircraft. During August and September, helicopters were used to locate fish on the spawning grounds and access these areas for collecting samples with small beach seines.

Spawning areas in the Taku River main stem were classified by habitat types that included main channel areas, side channels, side sloughs, tributaries, tributary mouths, upland sloughs, and lake systems. Information was also collected on the characteristics of specific redd sites (redd size, substrate composition, water velocity, depth, and water temperature).

Baseline samples have been collected from different areas of the Taku River to determine whether different stocks within the river can be distinguished. In 1986, sockeye salmon in the Taku River main stem were sampled for scales, and brains to determine the presence of the parasite Myxobolus neurobius, which has been useful in separating sockeye salmon stocks originating from different rivers in southeastern Alaska and British Columbia. Tissue samples for electrophoretic analysis and fork lengths and weights also were taken and are currently being analyzed.

The Taku River main stem was divided into four areas for analyzing stock separation information: the U.S. section and the lower, middle, and upper (lower Nakina River) Canadian main stem. These areas were characterized by habitat type: The U.S. section consisted of small tributaries flowing into the main stem, the lower Canadian main stem was an upland slough, and both the middle and upper Canadian main stem were side channel areas.

In 1984, only the last two-thirds of the sockeye salmon run was sampled and relatively few (93) fish were tagged with radio transmitters. Of these fish, 80 were tracked upriver: 56 provided distribution information (Table 1), 19 (24%) were caught in the Canadian gill-net fishery, and the remainder were either lost after tagging as the result of transmitter failure or tracking limitations or died as the result of handling stress or predation. In 1986, 282 sockeye salmon were tagged with radio transmitters. Of these fish, 179 were tracked upriver: 149 provided distribution information (Table 1) and 30 (17%) were caught in the Canadian gill-net fishery. Distribution information from 1984 and 1986 indicates that a large portion of the sockeye salmon run in the Taku River uses the main stem for spawning, whereas prior to 1984, it was believed that most of the run was destined for lake systems in the upper portion of the drainage.

Different run timings were observed for different stocks of fish entering the Taku River. In 1986, sockeye salmon destined for the upper Nakina River were the first to arrive; 54% of the fish entering the river during the first 3 weeks of the study (22 June-12 July) traveled to this area. In 1984 and 1986, most of the Kowatua Creek (Little Trapper Lake) stock entered the river during the second, third, and fourth week of July. The mainstem Taku River and Tatsatua Creek (Tatsamenie Lake) fish entered the river primarily between mid-July and early August.

The most important habitat type used for spawning was side channels. Small side channels just off the main channel as well as extensive side channel systems were used for spawning. Sockeye salmon also spawned in main channel areas, tributaries, tributary mouths, and upland sloughs.

Redd sites with a wide variety of characteristics were used by sockeye salmon in the main stem, although most fell within ranges previously observed. Most prepared redd sites had a substrate composition of less than 20% fine sediment, but some had unusually high (up to 80%) levels of fine sediment--higher than levels previously recorded. Many mainstem areas used for spawning had high levels of silt and sediment. Fish preparing redds in these areas essentially dusted

Table 1.--In-river distribution of returning adult sockeye salmon (*Oncorhynchus nerka*) on the Taku River in southeastern Alaska and northwestern British Columbia, 1984 and 1986. In parentheses is percent of fish by location and year.

Location	No. fish by year			
	1984		1986	
Taku River (main stem)	30	(54)	56	(38)
Nakina River (lower)	4	(7)	5	(4)
Total[a]	34	(61)	61	(42)
Nakina River (upper)	3	(5)	23	(15)
Inklin River			4	(3)
Kowatua Creek	4	(7)	33	(22)
Tatsatua Creek	13	(23)	26	(17)
Nahlin River			2	(1)
Hackett River	2	(4)		
Grand total	56	(100)	149	(100)

[a] Combined because the lower Nakina River flows into the Taku River main stem and is similar in habitat type.

sediment off prior to spawning. Many of these sites silted over again after spawning activity had ceased. Spawning areas in side channels and main channel areas, where silt levels were heaviest, tended to be associated with upwelling water.

A total of 507 fish were examined for brain parasites (Table 2). Only the lower Canadian main stem had a high (78%) infestation rate. Lower (13-17%) levels of parasitism were observed in the other areas.

Age data were obtained from 513 sockeye salmon from mainstem areas (Table 3). Fish using tributaries in the U.S. section resided in fresh water for 1 year (freshwater age 1 fish). Although freshwater age 1 fish also were observed in the lower and middle Canadian main stem, most (55% and 64%, respectively) fish in these areas were freshwater age 0 (residence time in fresh water less than 1 year). Most (71%) fish in the upper Canadian main stem were freshwater age 1 fish, yet the habitat type in this area is similar to that in the middle Canadian main stem where most of the fish were freshwater age 0.

Fish in the U.S. section and the middle and upper Canadian main stem were predominantly one year class (Table 4). The dominant year class in the U.S. section was 1981; and in the middle and upper Canadian main stem, 1982. Fish from the lower Canadian main stem were more evenly spread over several year classes.

Prevalence of zero-check sockeye salmon in Southeast Alaska

by

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INTRODUCTION

The life history of sockeye has been thought to almost always include on or more winters of growth as juveniles in freshwater lakes. This is certainly true for the vast majority of sockeye salmon both statewide and in Southeast Alaska. Most studies of sockeye, whether for allocation, enhancement, or population dynamics components, assume freshwater residence in a lake system. An increasingly broad audience accepts that juvenile sockeye salmon populations utilize riverine and estuarine habitat for rearing where lake habitat is unavailable. Adult fish utilizing habitat other than lake systems can be grouped as 'river-type', and are prevalent at numerous locations in Southeast Alaska where environmental conditions and habitat necessitate support an alternative juvenile life history. Many of these juveniles migrate to sea before one year has elapsed from egg deposition, and hence are referred to as 'sea-type' or 'zero-check' 1/ (Figure 1).

Zero-check sockeye were inferred by fry scale patterns in fish emerging below Harrison Lake in British Columbia by Gilbert (1918). Spawning adults were observed by Ward (1921) in Clear Creek, a tributary of the Copper River, where fry would not have access to a lake system. Zero-check sockeye have been observed in other Alaskan rivers west of Cape Suckling, in the Nushagak River (Ben Van Alen, ADF&G, Douglas, AK, pers. comm) and in the Susitna River (Scott Marshall, ADF&G, Douglas, AK, pers. comm). Sea-type sockeye have also been described in Kamchatka by Semko (1954), Krogius (1958), Krokhin and Krogius (1937), and Bugaev (1984).

In Southeast Alaska, zero-check sockeye salmon are present in most commercial fisheries throughout the region, but are found in escapements primarily in: (1) the Stikine River (McCart 1982; Oliver 1982; McPherson 1983; Walls 1984; Jensen 1986; and Wood et al. 1986); (2) the Taku River (McGregor 1985; 1986); (3) Lynn Canal rivers (McPherson et al. 1983; McPherson and Marshall 1986; McPherson 1987; and McPherson, in press); and (4) rivers that drain the Yakutat coastline (McBride and Brogle 1983; McBride 1984; 1986; and Riffe et al., in press) (Figure 2).

1/ Zero-check refers to freshwater age in the European formula for scale ageing where numerals preceding the decimal refer to freshwater annuli, numerals following the decimal are the number of marine annuli, and total age is the sum of these two numbers plus one.

BIOLOGY AND DEFINITIONS

To clarify some points in reference to zero-check sockeye let us remember that sockeye salmon are divided into two groups, lake-type and river-type. River-type adults spawn in river habitat and the progeny from the same geographic isolate (stock) outmigrate as zero-check, one-check, or even two-check fish, with the term 'check' referring to a true freshwater annuli. Semko (1954) and Wood et al. (1986) referred to river-type sockeye as those that reared in river lagoons or pools for at least one winter and sea-type as those that outmigrated as underyearlings. This is misleading since the juveniles rear in river habitat for varying lengths of time, from less than to more than one year. Zero-check sockeye, then, are simply offspring of river-type sockeye which migrate to sea without overwintering as fry.

What determines a zero-check sockeye?

This is not, at present, easily answered, but some river-type sockeye stocks are dissimilar both in habitat utilization and genetic composition. Electrophoretic studies demonstrated that the Chilkat Lake stock was significantly different at several loci from the river-type stock found along the mainstem of the Chilkat River (Jack Helle, National Marine Fisheries Service, Auke Bay, AK. pers. comm.). River-type sockeye salmon are unique in that they utilize habitat including glacially occluded mainstems, clear tributaries, slow moving side channels, sloughs, and lagoons, habitat more commonly used by pink and chum salmon. The latter two species do not rear overwinter in this habitat, instead outmigrating almost exclusively as zero-check fish. Not surprisingly, sockeye have been observed spawning within a few feet of pink and chum in the Lace River of Berners Bay, and at other locations.

Alaskan and Canadian river valleys which have been gouged by glaciers and subsequently filled with substrate over which meandering rivers and accompanying side channels, sloughs, and tributaries flow provide the most common habitat for river-type sockeye. Gravel beds, which may be up to several hundred feet deep as in the Tsirku Delta on the Chilkat Mainstem, occur along many of these rivers and are often associated with upwelling of clear, oxygen-laden groundwater. Groundwater of this nature is often warmer during winter months than surrounding river water. River-type spawning often occurrs near areas of upwelling. The warmer winter water temperatures in these areas may cause alevins to emerge earlier and fry to have an opportunity to begin growth earlier than their counterparts lying in gravel beds elsewhere.

STIKINE RIVER

The Stikine River sockeye salmon population is comprised of two groups, those fish that spawn at Tahltan Lake and all others, which are mostly river-type fish. Until 1982 it was believed that Tahltan Lake contributed approximately 90% of the Stikine River sockeye return (Bergmann 1978). This mistaken idea was due to the lack of escapement surveys in remote areas, the turbidity of much of the watershed, and a lack of stock identification techniques. Using scale patterns as a distinguishing criteria, McCart (1982) demonstrated that the return was comprised of a much greater proportion of non-Tahltan fish. This has been substantiated by subsequent studies (Oliver 1982, McPherson 1983; Craig 1983; Walls 1984; Jensen 1985 and 1986; Wood et al. 1986).

The Stikine River migration is intercepted in U.S. fisheries in Districts 104, 106, and 108 and Canadian fisheries on the lower river (commercial) and upriver near Tahltan Lake at Telegraph Creek (commercial and subsistence).

For the years 1979 to 1986 the estimated total return (catch plus escapement) of sockeye salmon to the Stikine River has ranged from approximately 50,000 to over 150,000 fish. River-type sockeye have comprised an estimated 40 to 60%, and zero-check fish 5 to 6% (2,500 to 9,000 fish), of the total return, respectively, in most years. Scale patterns analysis, egg size, electrophoresis, otoliths, length and sex data, or a combination of these data have been used to develop discriminating criteria for stock identification and catch allocation in the various studies. Sonar enumeration in the lower river, escapement counts from the weir at Tahltan Lake, and a combination of the stock-ID criteria are currently used to develop escapement estimates for the two groups.

I will use the Canadian inriver fishery as an example to provide a general overview of zero-check peak abundance in the Stikine River. The fishery operates from late-June through late-August with catches peaking from mid-July to early-August. Tahltan fish migrate earlier and catches of these fish generally peak between 6 - 12 July. Non-Tahltan Lake fish, comprised of river-types and lake-types from several small lakes in the drainage, peak in abundance two to three later. The zero-check component of this group comprises up to 20% of the weekly catches late in the season (McPherson 1983).

TAKU RIVER

The Taku River sockeye return is composed of several major populations which spawn in various locations in this large river system (Figure 3). The majority of lake-type fish return to Kuthai Lake, Tatsamenie Lake, and Little Trapper Lake. Major river-type spawning populations are found in Johnson Cr., Yehring Cr., near Canyon Island, along the Taku River Mainstem from South Fork Slough to the mouth of the Inklin River, along the lower portion of the Nakina River, and in the Tatsamenie and Hackett rivers. Scale samples collected since 1984 indicate that 10 to 50% of each river-type location is comprised of zero-check fish.

Migration and Exploitation

Sockeye bound for the Taku River enter inland waterways through Cross Sound and are exploited to a small degree in the U.S. Icy Strait purse seine Districts 112 and 114. Further exploitation occurs in the U.S. District 111 drift gillnet fishery and in the Canadian inriver commercial gillnet fishery. Total return in recent years (1984, 1985, and 1986) has averaged approximately 185,000 fish (Andrew McGregor, Alaska Dept. of Fish and Game, Douglas, pers. comm.). The District 111 fishery has taken an average of 73,000 fish annually during those years (approximately 80% of this total is bound for the Taku and the remainder for Port Snettisham), the Canadian inriver fishery catch has averaged 19,000 fish, and the escapement (mark-recapture) estimates have averaged approximately 95,000. Scale patterns analysis is used to allocate catches and a comprehensive scale sampling and tagging program operates just below the Canadian border at Canyon Island where samples taken from fish captured in fishwheels provide upriver stock and escapement estimates.

Migratory Timing

The relative abundance of age 0. fish climbs as the season progesses in District 111, at Canyon Island, and in the Canadian fishery, comprising up to 40% of these catches in some weeks (Figure 4). The consistency of these age composition data both among fisheries and years suggests that zero-check timing can be used to indicate timing of river-type fish, regardless of freshwater age. This is further supported by the fact that the proportion of age 0. scales samples collected at Canyon Island is closely mirrored by the run timing of mainstem river stocks as documented from spawning ground recoveries of tagged fish (Figure 5).

It is interesting to note that the peak of zero-check fish in the northern portion of District 112 occurred in statistical week 31, just prior to peak abundance of zero-check fish in the Taku fisheries. These fish were not bound for other zero-check producing systems in northern Southeast Alaska since the run timing of the only other significant stock of age 0. fish (Lynn Canal) peaks approximately one month earlier, and suggests that the presence of age 0. fish provides a means of stock identification through various fisheries.

The 1985 return of approximately 190,000 sockeye to the Taku River was comprised of an estimated 10% (19,000) age 0. fish.

LYNN CANAL

Chilkoot Lake and Chilkat Lake systems contribute most of the 400,000 to 600,000 total return of sockeye salmon to Lynn Canal each year. River-type stocks from the mainstem portions of the Chilkat River and from three of the four rivers that drain into Berners Bay also contribute to the catches, however (Figure 6). In 1986 56% of the Chilkat mainstem and 38% of the Berners Bay scale samples were zero-checks (McPherson, in press). Interestingly, the spawning areas on the mainstem of the Chilkat River are influenced to a greater extent by upwelling groundwater than the spawning locations in Berners Bay (Ray Staska, Alaska Dept. of Fish and Game, Haines, pers. comm.).

Magnitude

Aerial survey data suggests that the escapement of river-type fish to the Chilkat River is in the range from 5,000 to 15,000 fish, while the escapement to Berners Bay ranges from 2,000 to 10,000 (Ray Staska, Alaska Department of Fish and Game, Haines, pers. comm.) Catches from the combination of these stocks were 16,000 and 11,500 in 1985 and 1986, respectively (McPherson, 1985 and 1986 catch allocation reports, in press). The total return can be qualitatively placed between 25,000 and 40,000 fish in recent years. Of the total, 30 - 50% (9,000 - 20,000) are zero-check sockeye. Figure 6 illustrates the relative abundance of age 0. fish from these two stocks through the fishery.

Timing

The Lynn Canal drift gillnet fishery can be broken into two segments; an early season low effort, low catch segment comprised of a high proportion of Berners Bay/ Chilkat River fish, and a later, larger fishery which targets on the bulk of the Chilkoot Lake and Chilkat Lake migrations (Figure 8). The overall timing of the Berners/Mainstem stock is very early compared to that of Chilkoot Lake and Chilkat Lake. The mean date of harvest for the Berners/Mainstem stock in 1985 was 10 July compared to 12 August and 18 August for the Chilkoot and Chilkat stocks, respectively (McPherson, in press). The proportion of zero-check fish in Lynn Canal is relatively high during the first four weeks and is low thereafter (Figure 9), suggesting that the timing and presence of the Berners/Mainstem stock can be tracked by the zero-check component of the fishery.

YAKUTAT

The Yakutat area is home to the largest populations of zero-check sockeye salmon in the state, if not elsewhere as well. Several rivers along the Yakutat coastline are sockeye producers, including the East (Alsek), Alsek, Akwe, Italio, Situk, and Lost, of which only the Akwe and Situk are lake-type systems to any extent (Figure 10). All support terminal area, inriver and/or lagoon fisheries. Interception of these fish prior to their arrival at the terminal areas these fisheries occurs in Yakutat Bay and Manby Shore fisheries (Don Ingledue, Alaska Dept. of Fish and Game, Douglas, pers. comm.) and further west in the Kayak Island fishery offshore from the Copper/Bering fisheries (McBride et al. 1984).

Magnitude

The 1985 return is used to illustrate the magnitude of the return of zero-check sockeye to the Yakutat area. In 1985 the total estimated return (catch plus escapement) was 444,606 to the above mentioned rivers excluding catches in the interception fishery at Kayak Island. Of this total two rivers, the East with 55% (244,978 fish) and the Situk with 29% (128,619 fish), accounted for 84% of the return (Riffe et al., in press). All fisheries and escapements included zero-check fish, ranging from less than 1% in the Situk escapement above the weir to 98% in the East catch. Overall the return was composed of slightly more than a quarter of a million (57%) age 0. sockeye salmon, 93% of which was contributed by the East River. It is interesting to note that the East River was part of the Alsek River until the late 1960's and has since become a separate entity fed by clear ground-water upwelling through gravel deposits (Don Ingledue, Alaska Dept. of Fish and Game, Douglas, pers. comm.).

DISCUSSION

This is not a directed study, rather, the information presented herein is intended to provide an overview of the prevalence of significant populations of zero-check sockeye in Southeast Alaska. For detailed information and specific items, the appropriate literature should be referenced in the 'Southeast Alaska zero-check sockeye salmon literature' list attached.

In addition to utilizing habitat unique to most sockeye populations, zero-check sockeye provide other tools as well. As mentioned earlier, age composition data can be used to identify river-type populations migrating through several commercial fisheries. From an enhancement standpoint, age 0. fish provide an opportunity to realize returns one year earlier plus greatly reduce the overall cost of raising fish by eliminating the need to overwinter the fry for one year in a hatchery environment.

Some of the information presented here is speculative and further research needs to be done to document life history and other aspects. Areas of particular interest include: (1) documentation of the zero-check scale pattern as it relates to inriver rearing and outmigration; (2) estimation of the productivity of river-type sockeye as they may be less productive than lake-type fish; (3) documentation of the role of groundwater as it relates to the proportion of zero-check fish in a river-type population; (4) the success of zero-check sockeye salmon enhancement in the natural setting; and (5) the prevalence of sockeye salmon populations in other areas of the state.

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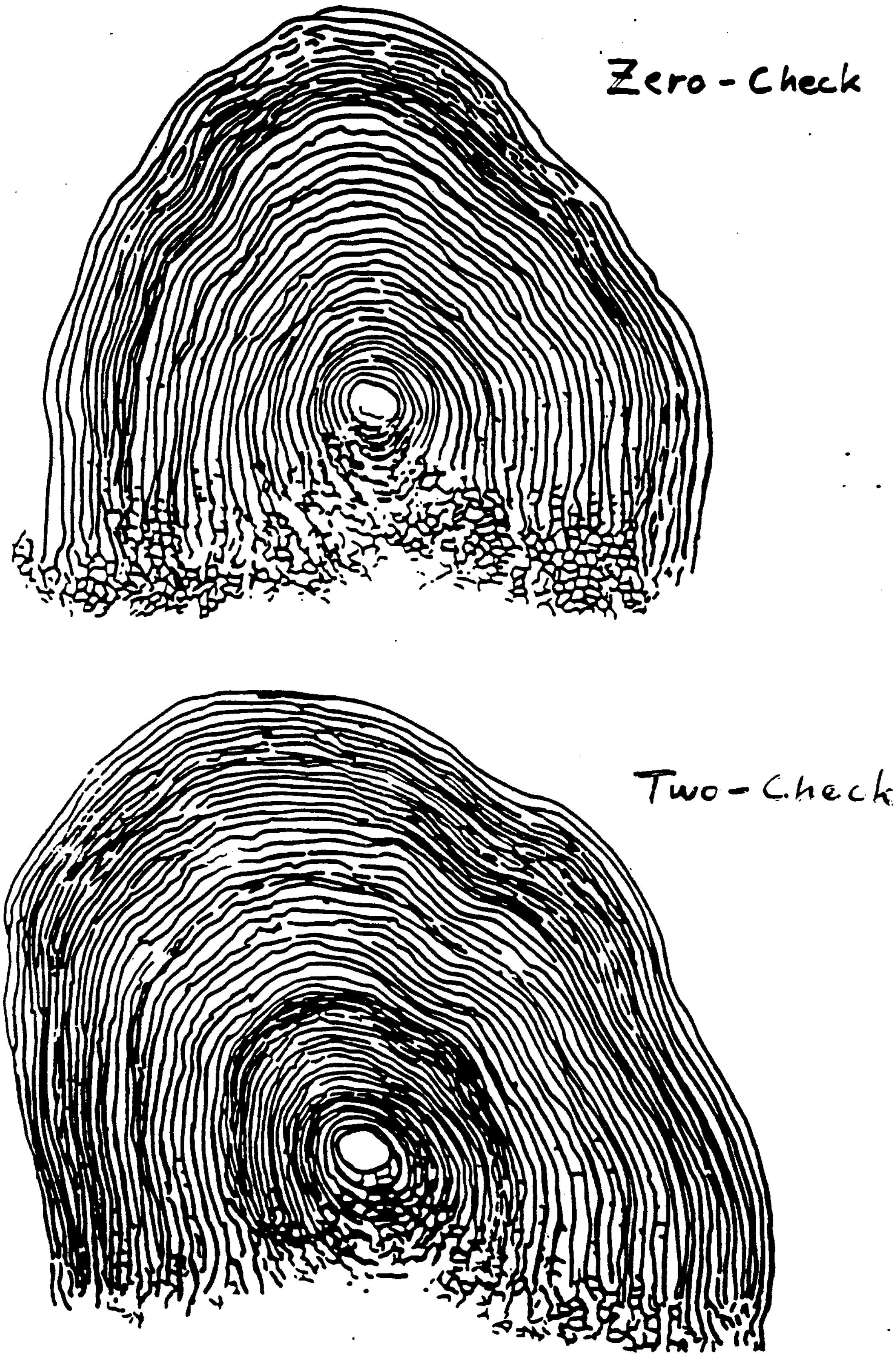

Figure 1. Images comparing a typical zero-check (river-type) to a two-check (lake-type) sockeye salmon scale pattern.

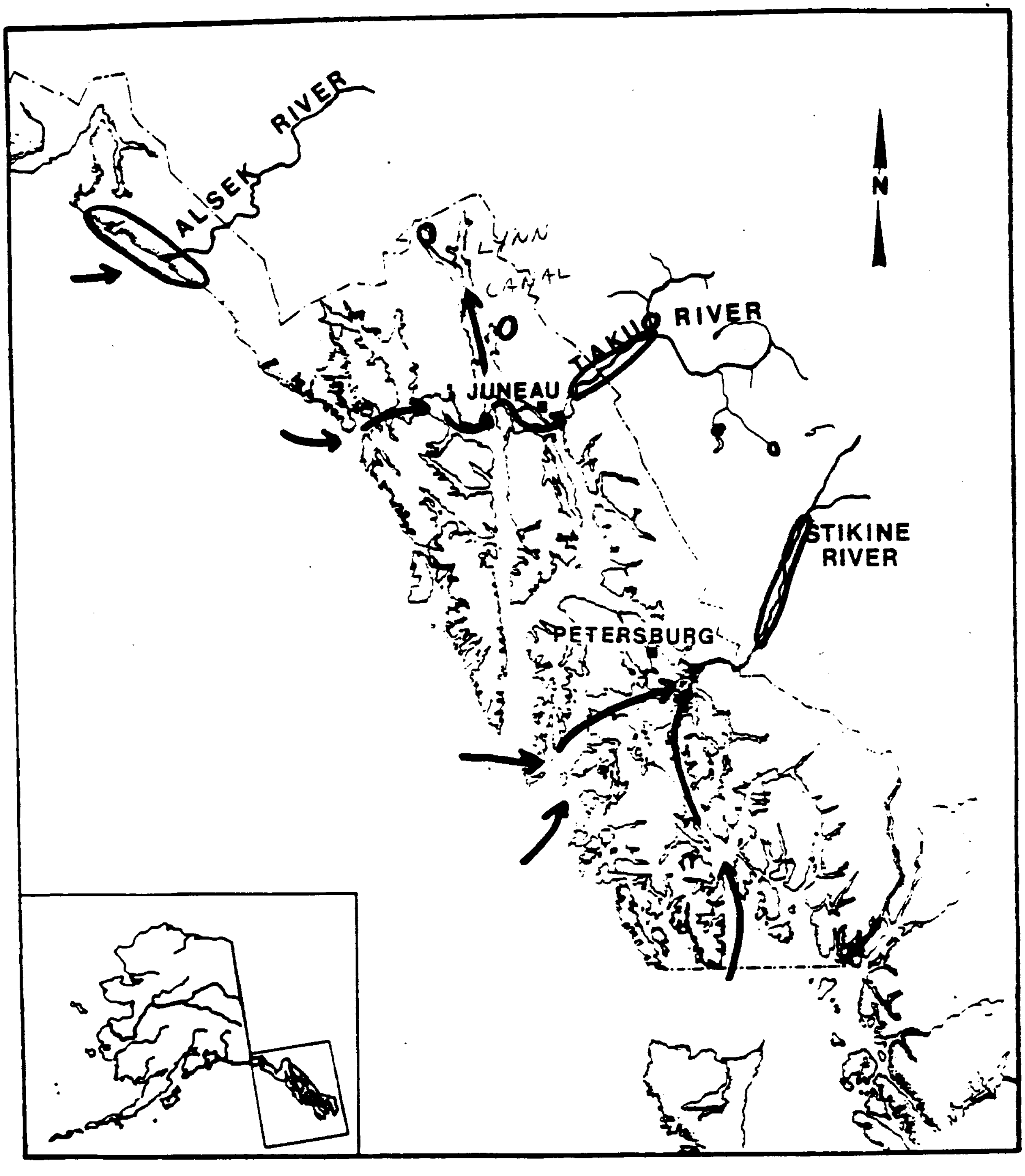

Figure 2. Map of Southeast Alaska showing locations of major populations of zero-check sockeye salmon and migration routes.

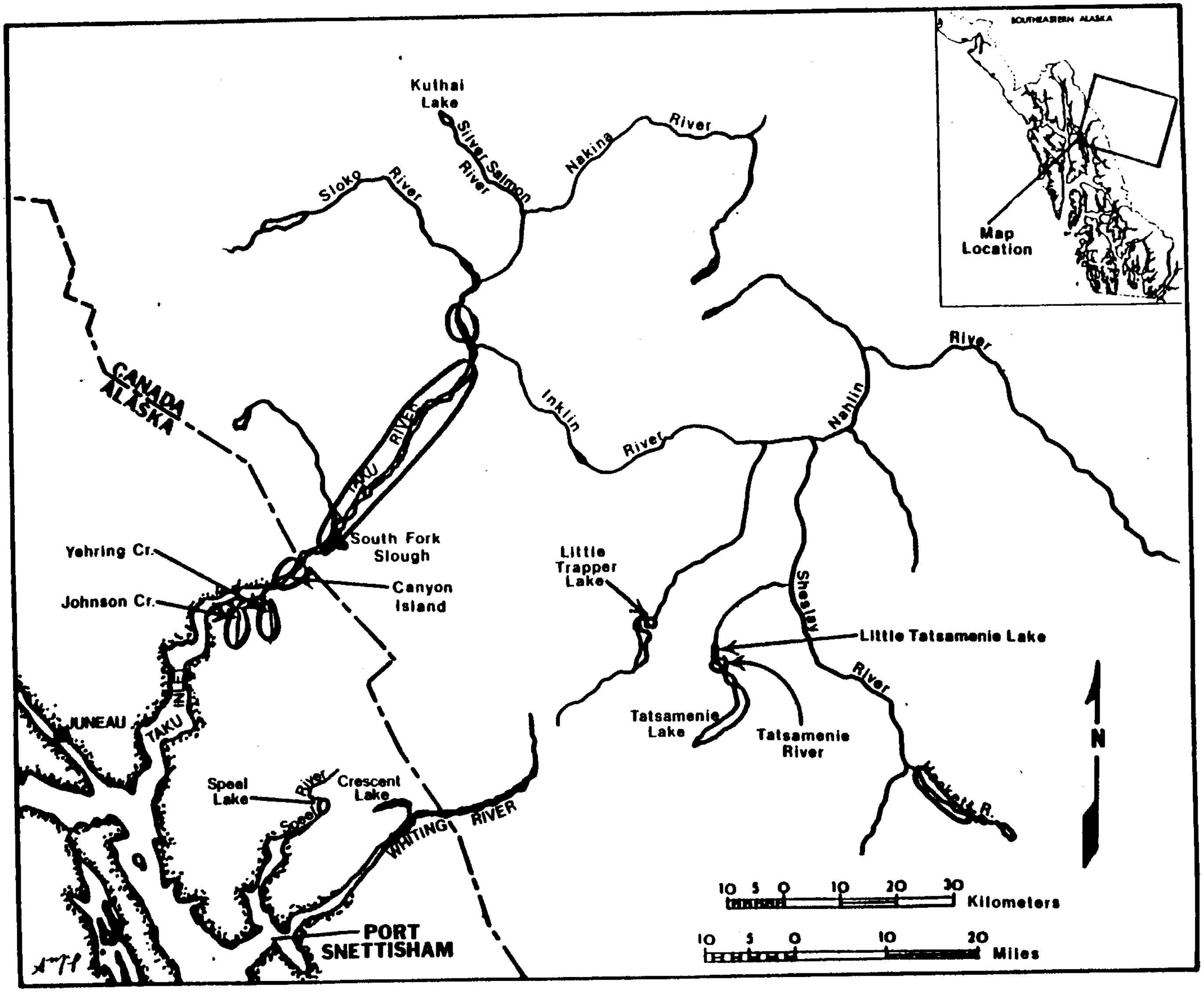

Figure 3. Map of the Taku River drainage showing locations of zero-check sockeye populations.

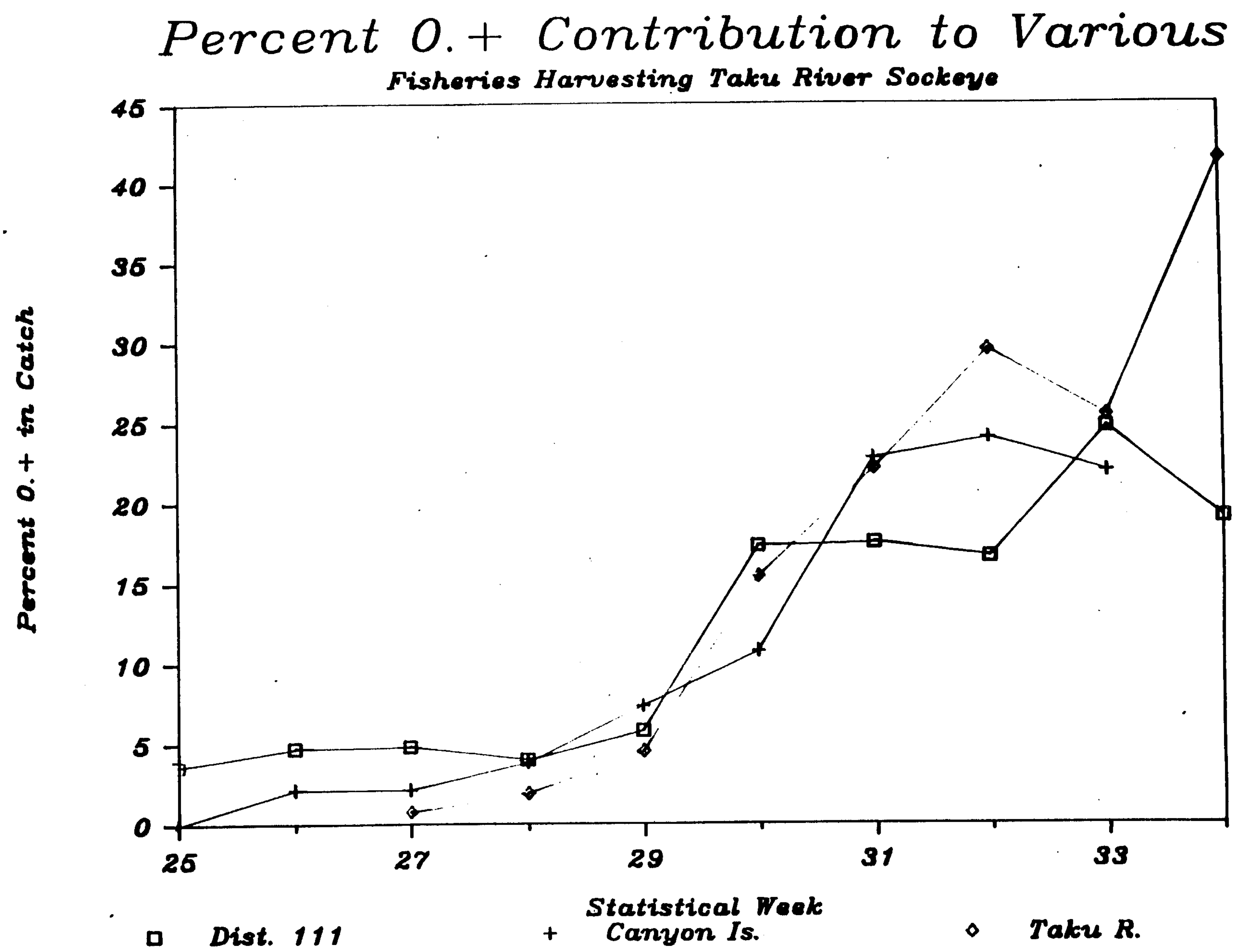

Figure 4. The weekly percent of age 0. fish in three fisheries which harvest Taku River sockeye.

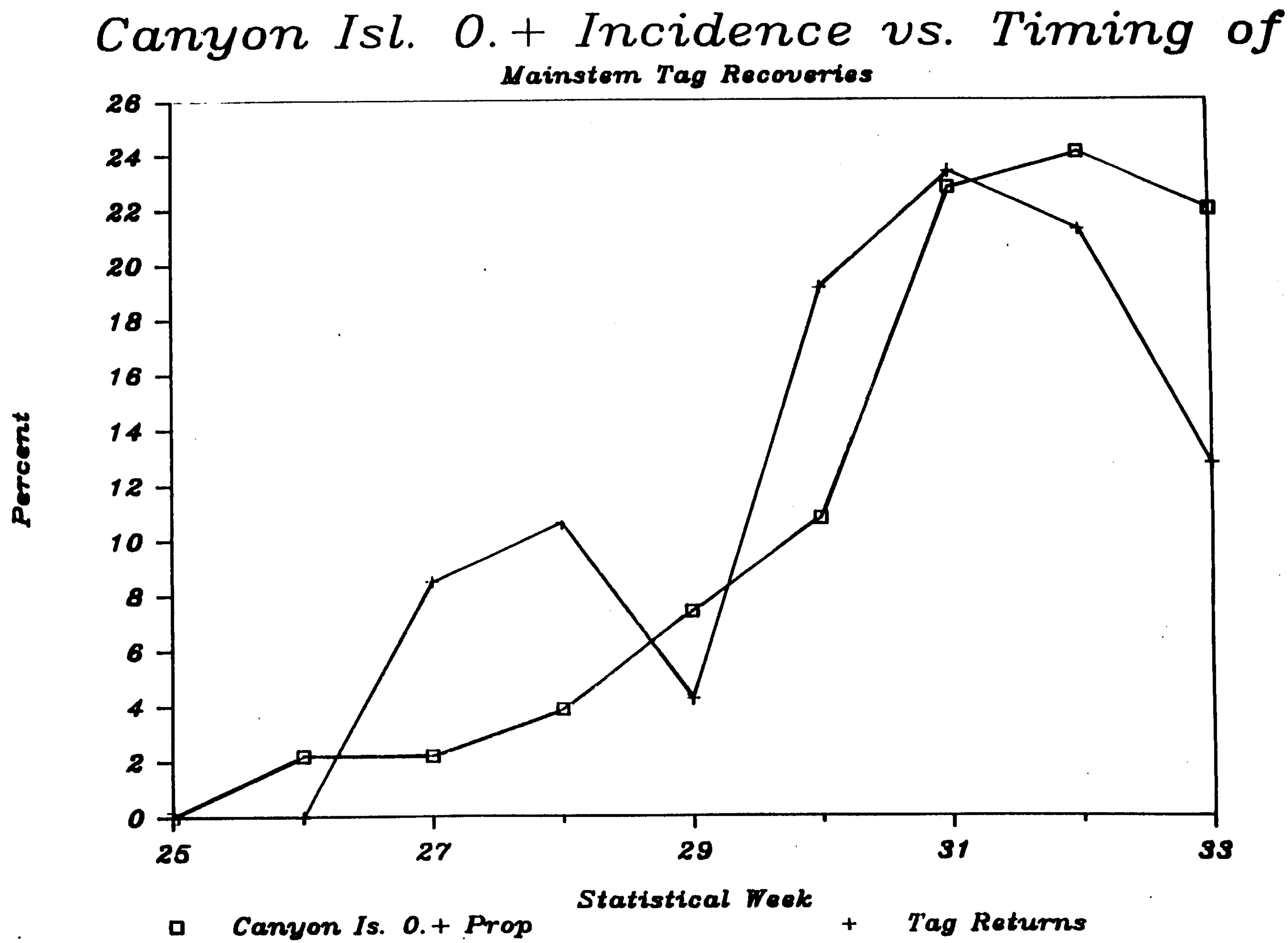

Figure 5. The weekly percent of age 0. sockeye at Canyon Island compared to the weekly percent of tag returns.

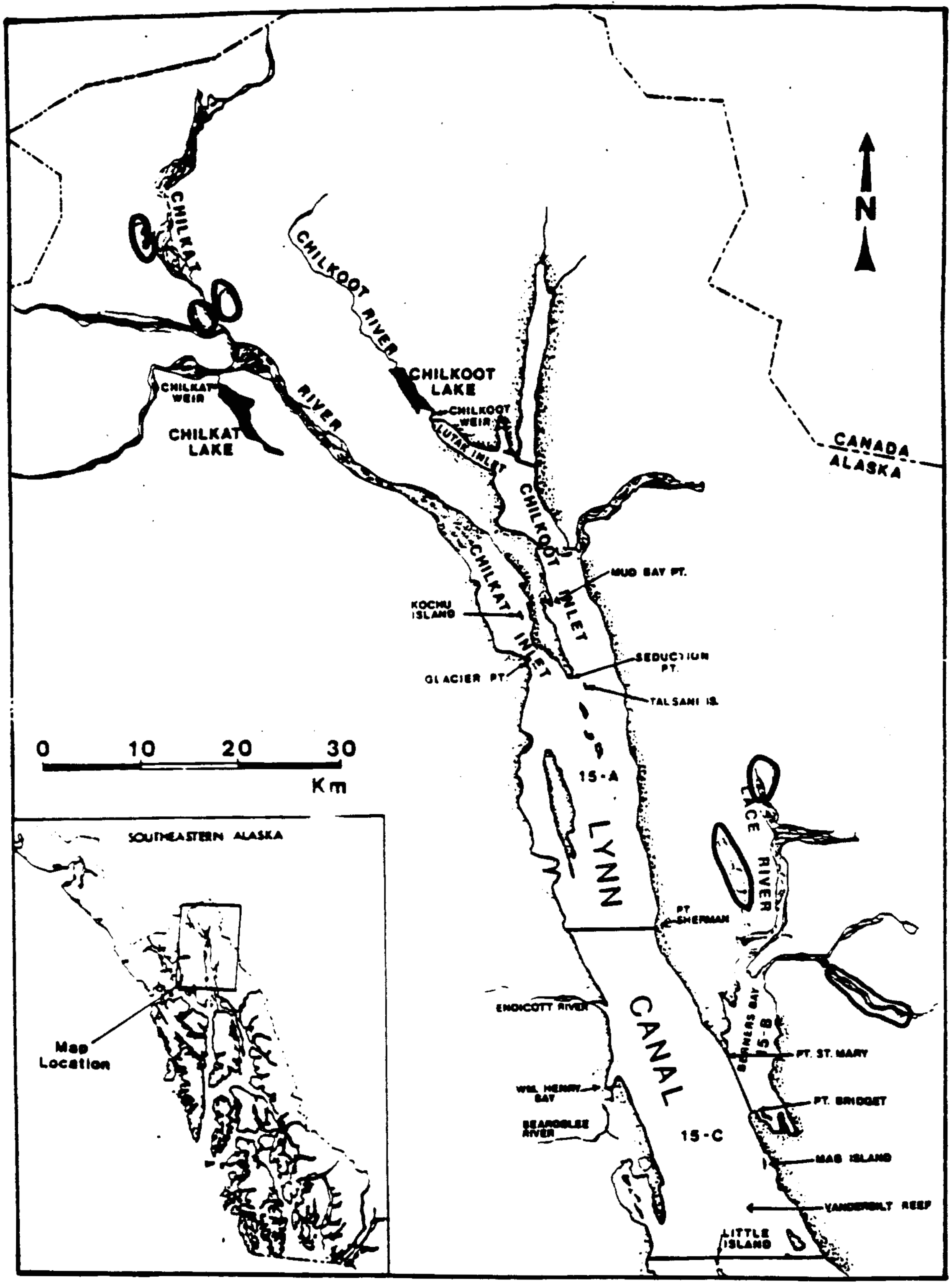

Figure 6. Map of Lynn Canal showing the fishing district and sections (e.g., 15-C) and principal spawning and rearing areas.

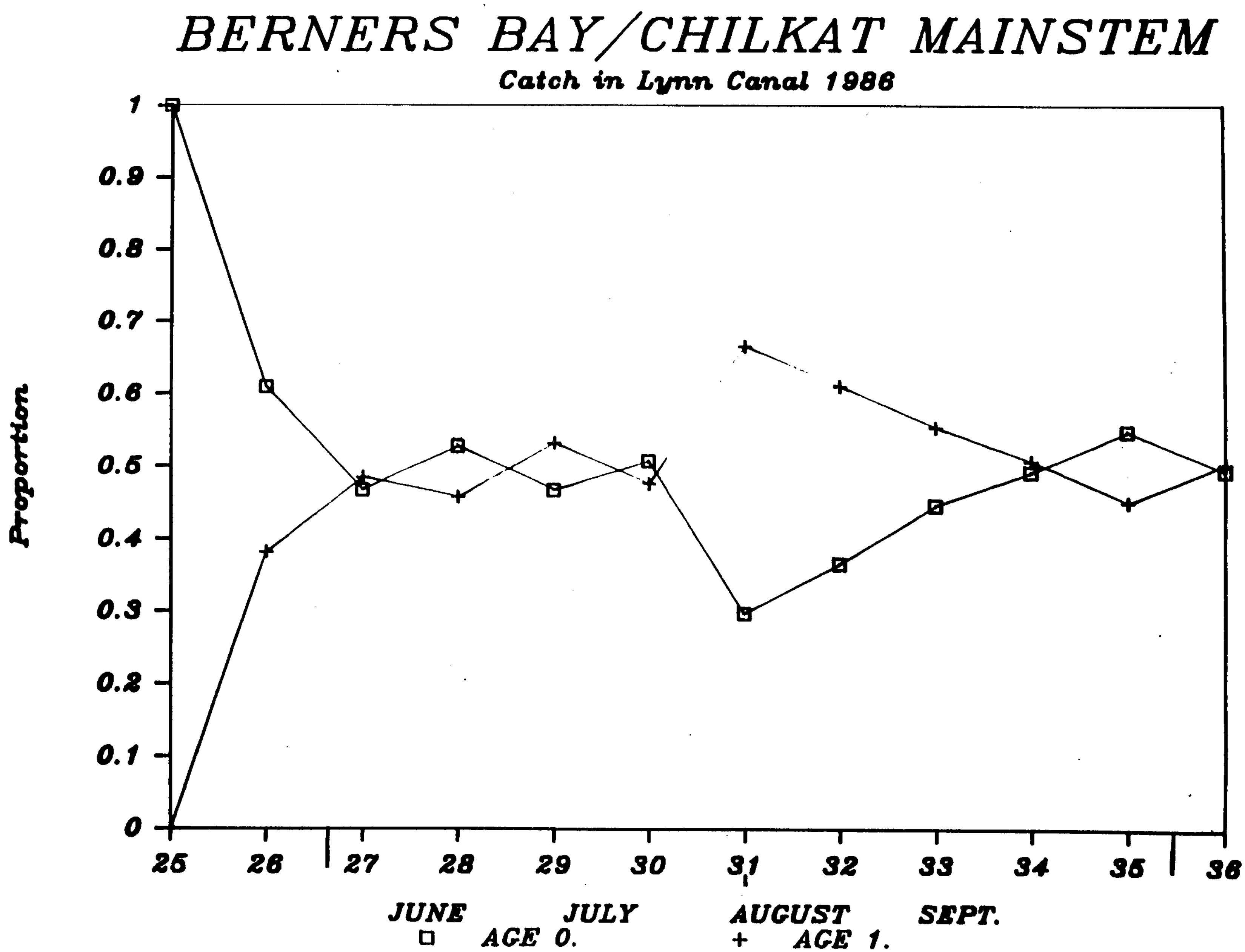

Figure 7. The weekly proportion of age 0. sockeye in the catch of Berners Bay/ Chilkat Mainstem fish in Lynn Canal.

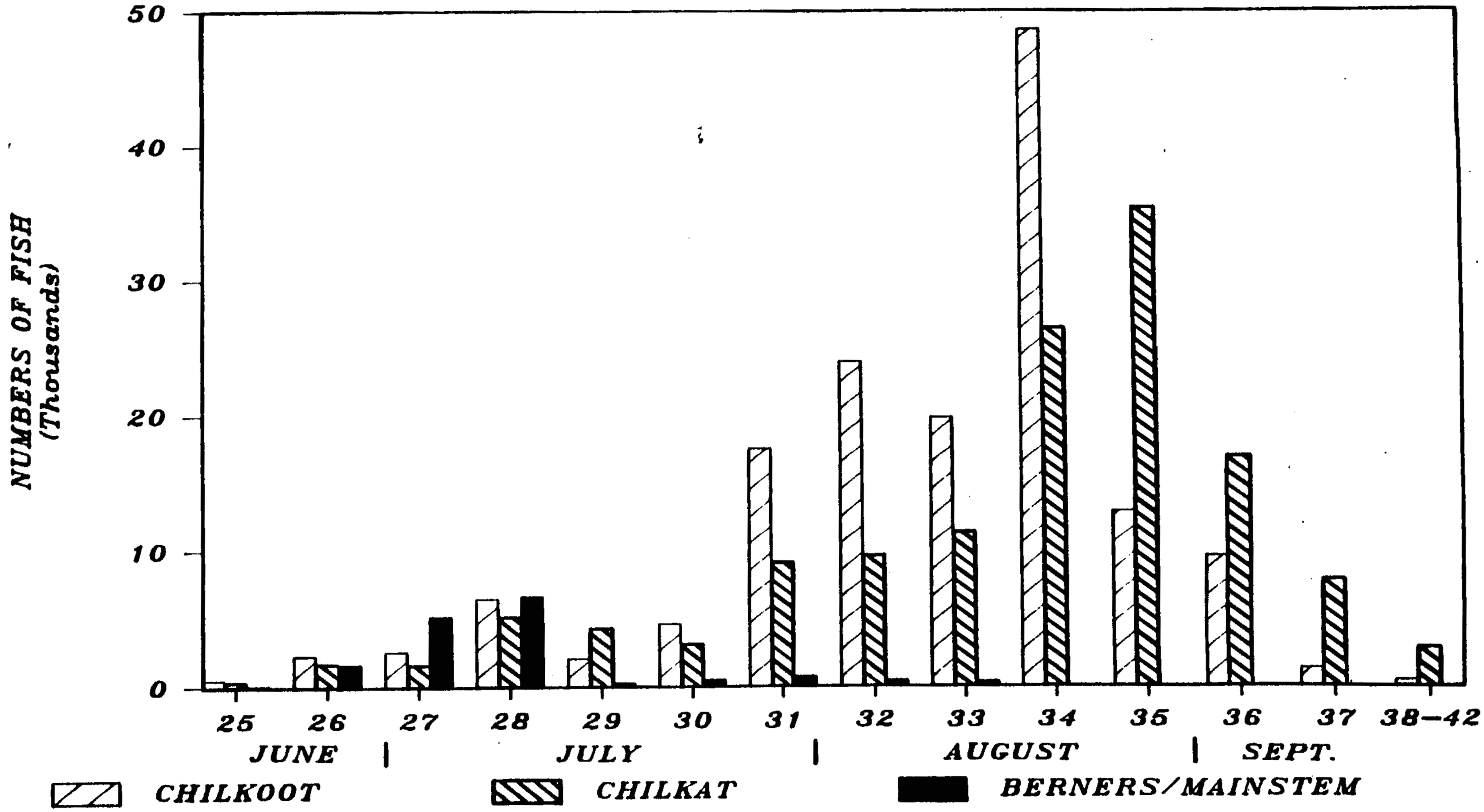

Figure 8. Weekly catch by stock in Lynn Canal.

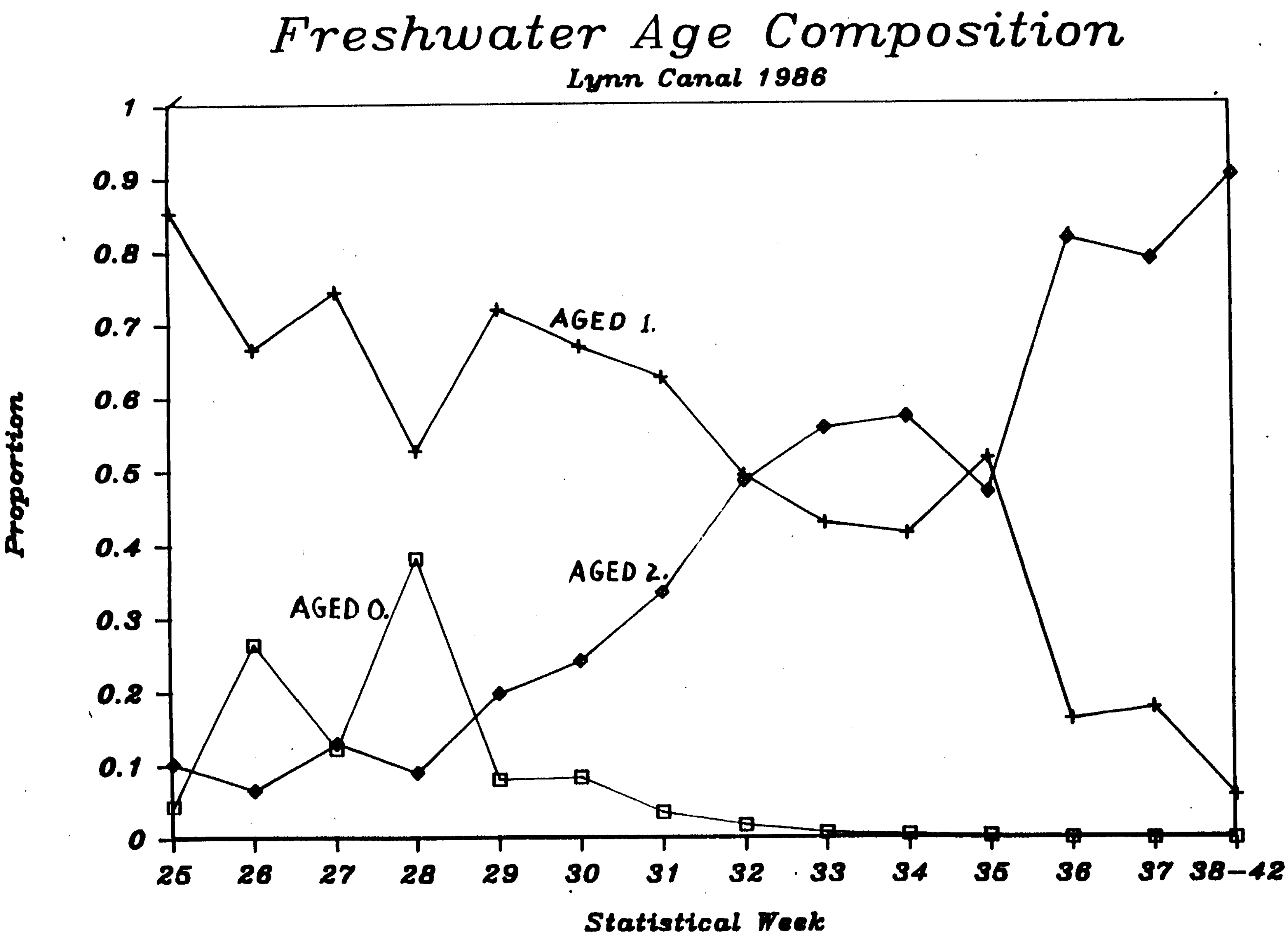

Figure 9. The weekly age composition by freshwater age class in Lynn Canal.

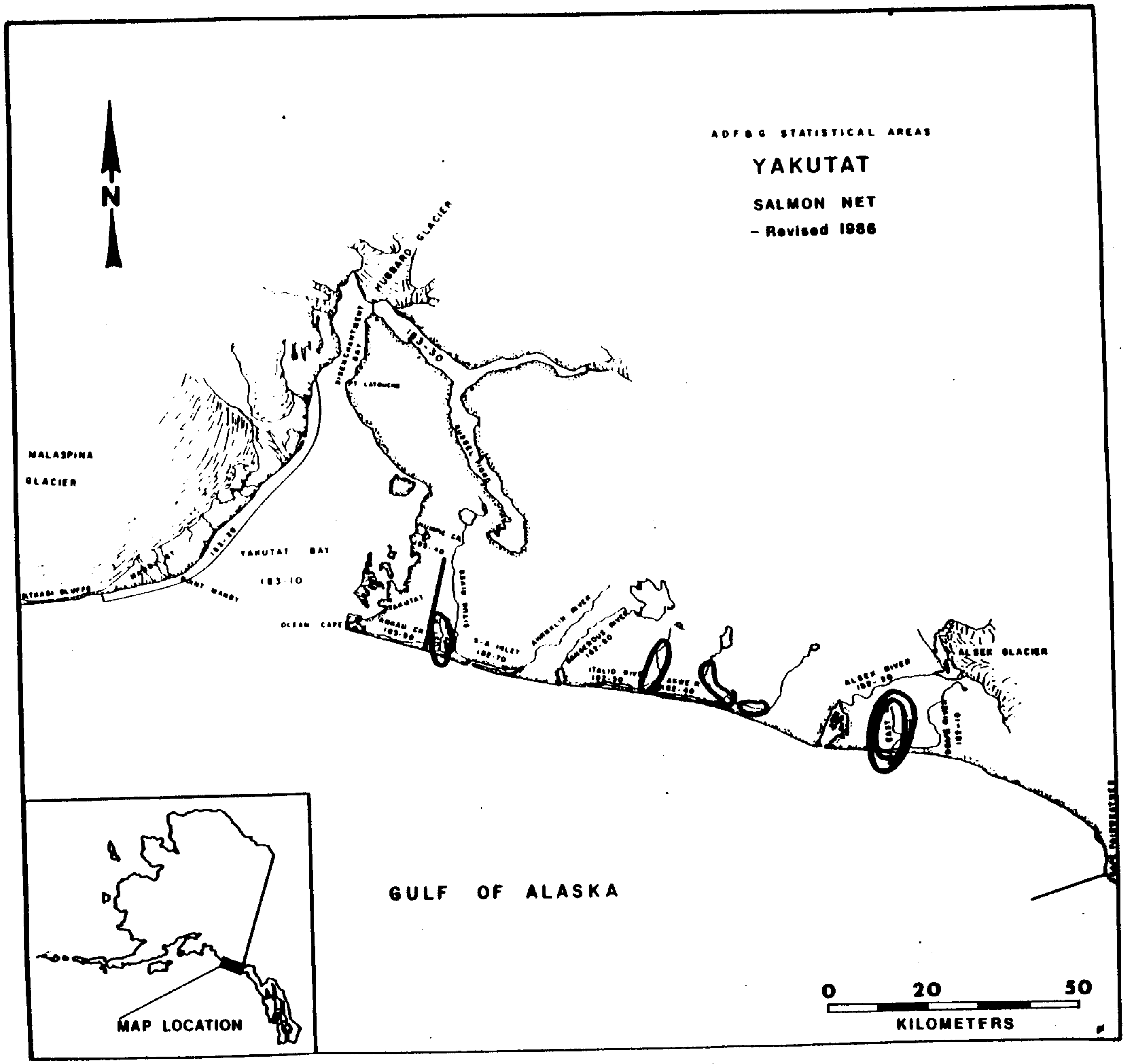

Figure 10. Map of the Yakutat area showing locations of major zero-check sockeye populations.

DISTRIBUTION OF THE BRAIN PARASITE MYXOBOLUS NEUROBIUS IN SOCKEYE SALMON IN SOUTHEAST ALASKA AND USE OF THE PARASITE FOR STOCK IDENTIFICATION

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In 1982 and 1983, the Canadian Department of Fisheries and Oceans collected samples of spawning sockeye salmon from several major spawning rivers in Southeast Alaska and British Columbia. (Pacific Salmon Commission 1987). The sporozoan parasite, Myxobolus neurobius, was found to be present in all but two of the Alaska stocks - Chilkat and Chilkoot Lakes. In contrast, only the coastal portions of British Columbia were found to be infested with the parasite. Most lake systems were either heavily parasitized with most of the fish having the parasite or they lacked any evidence of its presence at all.

While only a few lake systems had been examined, the possibility existed that the parasite presence or absence might serve as a useful biological tag for separating Alaska and British Columbian sockeye salmon stocks, particularly when combined with other stock separation techniques. Further baseline data was needed on the distribution and biology of the parasite.

In 1986, the Auke Bay Laboratory examined sockeye collected from 24 lakes throughout southeast Alaska. (Table 1). Some of these lakes had been previously sampled, but sampling 3-4 years later permitted us to examine interannual variability. Only Steep Creek (a glacial lake system) completely lacked any evidence of the brain parasite. Chutine Lake and Lace River had almost no parasitism (2 and 5%). The Stikine River, the Chutine River, the Naha River, and Luck Lake had 40-50% prevalance. The remaining systems had greater than 72% infection and 14 systems had greater than 95% prevalance. The Taku River had a wide variation in prevalance ranging from 0% to 78% depending on location. (Figure 1).

The life cycle of Myxobolus is still largely unknown. Dana (1982) hypothesized a direct life cycle based on transmission experiments. He was able to directly infect juveniles with the spores from the brains of adult salmon. In a direct life cycle, no intermediate hosts are necessary for the completion of the life cycle. The fry would injest spores released from the decay of spawning adults and the spores would mature as the fish grew older.

The life cycle of a related myxosporidean fish parasite has been worked out since the publication of Dana's thesis. The causative agent for whirling disease is a related sporozoan, Myxosoma. Myxosoma spores are injested by tubificid oligochaetes which release an actinosporean. This actinosporean is injested by the fish and the spores develop in the fish. (Wolf and Markiw 1984). Myxosoma has also been found in the brain of the blue heron and seabirds may act as vectors in the distribution of the parasite (Meyers et al. 1970). Similarly, we are exploring the possibility that seabirds, especially gulls, may partially explain the distribution of *Myxobolus*. Most of the lakes that had the parasite present are not far from the sea and the inland systems and glacial streams where gulls are largely absent also seem to lack the parasite.

Commercial fisheries samples from areas 106, 104 and 111 were examined for the presence of the parasite on a weekly basis (Table 2). The data will be combined with electrophoretic and scale data from the same fish to determine the feasibility of separating stocks of sockeye salmon using combinations of the above techniques. Initial comparison of parasite prevalance by week with existing estimates of Alaskan stock contributions to the fisheries suggests that parasites show promise as a stock tag.

In addition, we are beginning work on the physiological effect of *Myxobolus* on its host. It is assumed that *Myxobolus* has little or no effect on sockeye salmon which would support its use as a tag. A good tag should have little effect on the survival of the fish. It seems odd that a fish with thousands of 12 micron spores in its brain cavity would not be affected in some manner. We are currently beginning an investigation on the effect of the parasite on growth, osmoregulation, salinity tolerance and swimming performance.

Another parasite that shows promise as a tag for separating Alaskan and Canadian salmonids is the protozoan flesh parasite, *Henneguya*. The distribution of this parasite in British Columbian fishes shows much the same pattern as the distribution of *Myxobolus* (Boyce et al. 1985). It is largely absent from Canadian river systems except for coastal streams. Very little is known about the distribution of *Henneguya* in Alaskan sockeye.

Boyce, N.P., Z. Kabata and L. Margolis. 1985. Investigations of the distribution, detection and biology of *Henneguya salminicola* (Protozoa, Myxozoa), a parasite of the flesh of Pacific salmon. Canadian Technical Report of Fisheries and Aquatic Sciences. No. 1405.

Dana, d. 1982. The biology of transmission of *Myxobolus neurobius* Schuberg and Schroder, 1905. M.S. Thesis, Simon Fraser University, 117 pages.

Meyers, T.U., J. Scala, and E. Simmons. 1970. Modes of transmission of whirling disease in trout. Nature 277: 622-623.

Pacific Salmon Commission. 1987. Stock identification of sockeye salmon using biological markers. Report TCNB/TR (87) 1.

Wolf, K. and M. E. Markiw. 1984. Biology contravenes taxonomy in the *Myxozoa*: new discoveries show alternation of invertebrate and vertebrate hosts. Science 225: 1449-1452.

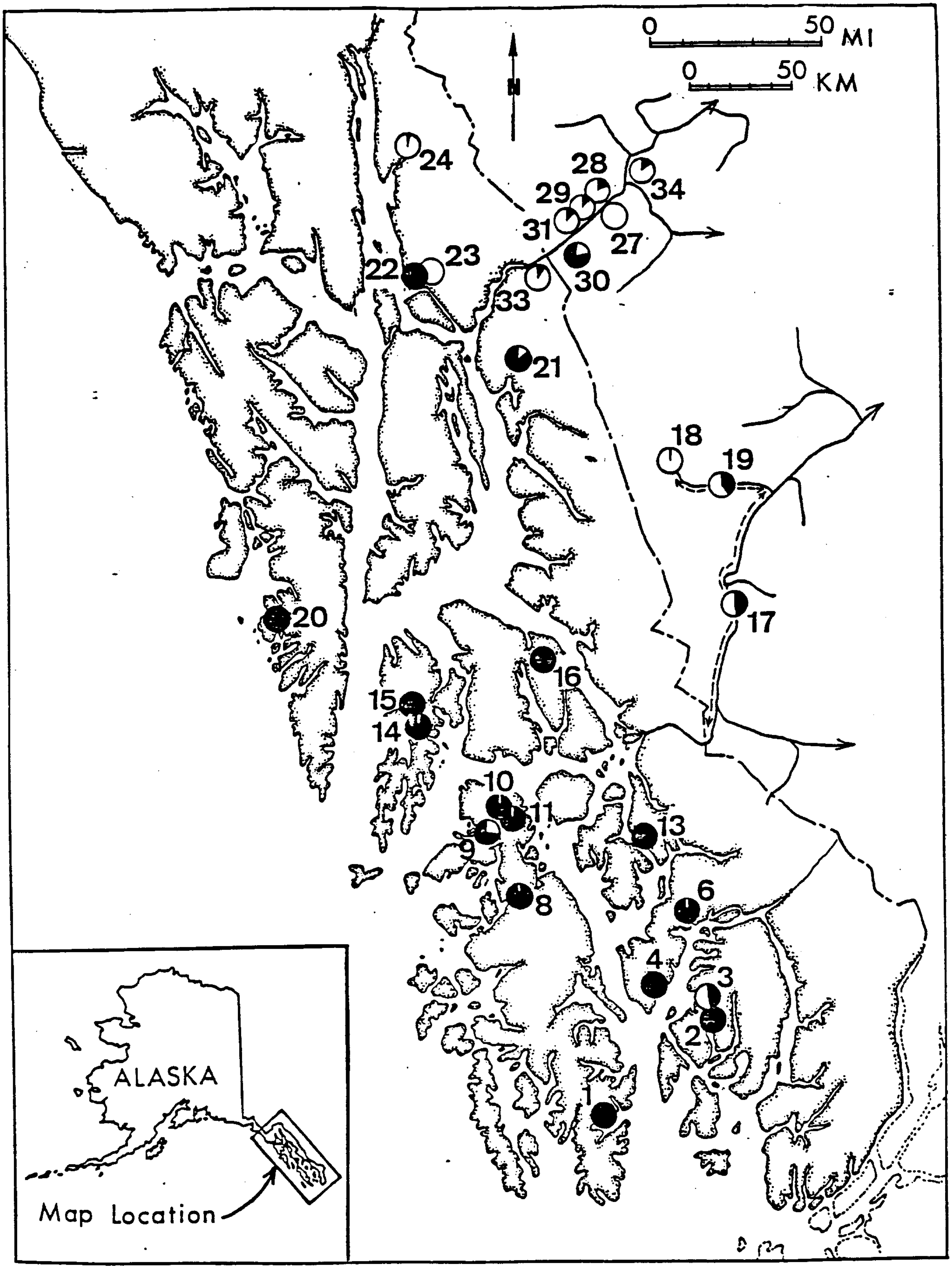

FIGURE 1. Percentage sockeye salmon parasitized by Myxobolus neurobius in 1986 baseline systems surveyed. Numbers correspond to Table 1 to identify system names. ● = 100 % parasitized; ○ = 0 % parasitized.

3/3/87

TABLE 1. Occurrence of brain spore *Myxobolus neurobius* in sockeye salmon collected from southeastern Alaska and British Columbia watersheds, 1986. P/T = number fish parasitized/number fish sampled, and % P = percentage fish parasitized.

BASELINE	GEOGRAPHIC LOCATION	P/T	% P
1. Kegan Lk.	SE Prince Wales Is.	50/50	100
2. Leask Lk.	W Revillagigedo Is.	41/41	100
3. Naha	W Revillagigedo Is.	38/79	48
4. Helm Lk.	E Behm Canal	50/50	100
5. Karta weir	E Prince Wales Is.	8/10	80
6. McDonald Lk.	NE Behm Canal	49/50	98
7. Luck Lk.	NE Prince Wales Is.	10/20	50
8. Upper Sarkar	NW Prince Wales Is.	43/44	98
9. Sutter Cr.	N Kosciusko Is.	26/36	72
10. Red Bay Lk.	N Prince Wales Is.	51/53	96
11. Salmon Bay Lk.	" " " "	39/41	95
12. Shaul Cr.	" " " "	10/10	100
13. Thoms Lk.	SW Wrangell Is.	50/50	100
14. Alek Lk.	W Kuiu Is.	44/45	98
15. Kutlaku Lk.	" " "	42/42	100
16. Petersburg Lk.	E Kupreanof Is.	50/50	100
17. Stikine R.	mainstem	23/50	46
18. Chutine Lk.	Stikine R.	1/64	2
19. Chutine R.	Stikine R. trib.	20/50	40
20. Redoubt Lk.	W Baranof Is.	56/56	100
21. Speel Lk.	Stephens Passage	85/100	85
22. Auke Cr.	Juneau	32/32	100
23. Steep Cr.	Juneau	0/28	0
24. Lace R.	Lynn Canal	3/60	5
Taku River			
25. Canoe Sl.	mainstem	0/2	---
26. Chum/Salmon Sl.	"	1/7	---
27. Coffee Sl.	"	0/30	0
28. Honakta Sl.	"	11/59	19
29. Shustahini Sl.	"	17/128	13
30. South Fork Sl.	"	46/59	78
31. Tuskwa Sl.	"	8/60	13
32. Fish Cr.	tributary	8/20	40
33. Yehring Cr.	"	11/89	12
34. Nakina R.	"	8/53	15

2/26/87

TABLE 2. Occurrence of brain spore *Myxobolus neurobius* in sockeye salmon sampled from commercial catches by district and week. P/T = number fish parasitized/number fish sampled, and % P = percentage fish parasitized.

COMMERCIAL FISHERY

DISTRICT	WEEK	P/T	% P
104	28	100/296	34
	29	35/139	25
	30	36/184	20
	31	40/272	15
	32	25/190	13
	33	55/253	22
	34	21/119	18
	35	58/255	23
106-30	25	40/47	85
	26	46/60	77
	27	65/101	64
	28	FISHERY CLOSED	
	29	59/92	64
	31	NO SAMPLES	
	32	56/102	55
	33	37/100	37
	34	31/103	30
106-41	25	118/152	78
	26	58/89	65
	27	50/88	57
	28	FISHERY CLOSED	
	29	" "	
	30	65/97	67
	31	54/90	60
	32	53/89	60
	33	38/89	43
	34	9/43	21
108	30	26/81	32
	31	23/93	25
	32	28/74	38
111	25	48/55	87
	26	30/40	75
	27	35/74	47
	28	19/136	14
	29	23/138	17
	30	39/138	28
	31	17/69	25
	32	18/92	20
	33	1/7	---
	34	NO SAMPLES	
	35	7/27	26

TABLE 2. continued

TEST FISHERY

DISTRICT	WEEK	P/T	% P
106-30	24	8/23	35
	27	88/121	73
	28	84/113	74
106-41	24	10/25	40
	25	38/50	76
	26	60/88	68
	27	69/116	59
	28	99/152	65
	29	67/111	60
108-30/40	26	4/39	10
	28	5/23	22
	29	14/18	78
	30	10/16	63
108-50/60	26	3/35	9
	28	4/20	20
	29	11/56	20
	30	13/55	24

The Manipulation of Lakes For Sockeye Salmon (*Oncorhynchus nerka*) Rehabilitation and Enhancement

by

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M. Haddix

and

G. B. Kyle

Presented at the Southeast Alaska Sockeye Salmon Workshop, April 15th and 16th, 1987, Juneau, Alaska.

BACKGROUND

The Department of Fish and Game launched the statewide limnology program in 1979. The program was initiated under the Division of Fisheries Rehabilitation, Enhancement, and Development; and is aimed at rehabilitation and enhancement of sockeye salmon by manipulating nursery lakes through nutrient enrichment and fry stocking.

Early on, it was decided that a systematic approach to field investigations and decision-making regarding the benefits of these techniques to sockeye populations would be required. For example, a "Guideline" to lake fertilization was published in 1979 and became the "how to" manual for department staff and cooperators. The guidelines set forth the standards for the types and amounts of data to be obtained from lakes prior to enrichment and, importantly, include the types of information required to judge whether or not fertilizer application has done any good. The latter encompasses what is known as project evaluation. Evaluation is keyed to several benchmarks or trophic responses of the lake ecosystem. These include responses of the phytoplankton (primary production); responses of the zooplankton (secondary production); and responses of the rearing juvenile sockeye salmon (tertiary production).

In conjunction with cooperators such as the U. S. Forest Service, regional aquaculture associations, and others, lakes that would serve as candidates for study were selected from around the state. Sockeye salmon lakes across Alaska can be crudely categorized according to the appearance of the water within the lake basin: clear, stained or tea-colored, and silty or milky because of intrusion of glacial meltwater (Koenings et al. 1986). Lakes finally chosen as study lakes included representatives from each of these categories.

FINDINGS

General

Synthesis of research results obtained from lakes around the state formed the basis for the development of predictive models on the carrying capacity and production of sockeye salmon systems. By using performance data from a variety of lakes representing specific lake types, we were able to classify lakes into categories which reflect the limitation to sockeye salmon production. Lakes limited by the low numbers of juvenile recruits able to enter the rearing area were "recruitment limited." Lakes limited by the quality and quantity of forage production in the rearing arena were "rearing limited." Each type of limitation was found to be linked to specific characteristics of the smolt populations (age, size, number) and to the rearing arena (forage, temperature, light). In particular, the rearing limited lakes were further classified into "forage limited" and "environment limited" systems (Koenings and Burkett 1987).

We grouped lakes according to numbers of sockeye salmon fry per lake unit (population density) and lake fertility (capacity to produce suitable forage). Production in these two groups of lakes is described and sub-divided as follows:

A. Recruitment limited (low initial input and density of fry)

   1. Escapement limited (density independent)
   2. Spawning area limited (density indepdent)

B. Rearing limited (poor lacustrine conditions or fry-forage interaction)

   1. Forage limited

      a. poor quantity and quality of forage base (density dependent)
      b. poor spatial/temporal concurrence of fry and forage (density independent)

   2. Environment limited

      a. unfavorable temperature regime (density independent)
      b. short growing season (density independent)

The classification indicates that rearing limitation can be either forage or environment based or both; that forage limitation can be density dependent or independent; and that density independent growth can be either recruitment or rearing limited.

Use of this lake classification scheme provides an approach for the matching of the appropriate enhancement strategy (e.g., lake plants of fry or lake enrichment) to the limiting feature of the lake. Our investigations have linked one physical feature of lakes (euphotic volume) to the base of the food chain and, in turn, to sockeye salmon production. We have distilled out a series of equations which can be used to forecast baseline sockeye salmon production from lakes, and to determine numbers of rearing fry (Koenings and Burkett 1987). These findings can also be used to establish escapement goals for sockeye salmon lakes.

From experimental manipulations of fry densities, we have developed two predictive equations:

1. $\text{Log SW} = 5.78 - 1.09 \log \text{SD (EV)}$; $r^2 = 0.99$
2. $\text{\% FWS} = 1.89 + 51.86 \log \text{SW}$; $r^2 = 0.92$

Also, from empirical observations on nursery lakes, we have formulated four relationships:

3. $\text{SN} = -42{,}021 + 23{,}010 \text{ EV}$; $r^2 = 0.97$
4. $\text{Log SL} = 1.71 + 0.31 \log \text{SW}$; $r^2 = 0.99$
5. $\text{Log Ocean Survival} = -2{,}647 + 0.035 \text{ SL} - 0.000142 (\text{SL})^2$; $r^2 = 0.36$
6. $\text{ASP} = -95{,}000 + 2{,}498 \text{ EV}$; $r^2 = 0.95$

   Where: ASP=Adult Sockeye Production

   EV=Euphotic Volume units (millions of m^3)

   SW=Smolt Weight (gm)

SN=Smolt Numbers

SL=Smolt Length (mm)

SD=Stocking Density per unit EV

For nursery lakes capable of supporting density-dependent growth, a stocking density (SD) of ~110,000 fry EV^{-1} would result in forecasting the production of a 1.9 g age 1. smolt (equation 1). This corresponds to a threshold sized smolt of 2 g which is then used to estimate a brood-year freshwater survival (FWS) at 18% (equation 2). The original stocking density of 110,000 fry/EV multiplied by a survival to smolt of 18% yields a smolt population estimate of 20,000 smolts/EV. This is very close to the 23,000 smolts/EV found in the empirical relationship derived from rearing limited lakes (equation 3).

The threshold smolt size of 2 g can be converted to an equivalent length (equation 4) of 64 mm which results in a predicted ocean survival of 10% (equation 5). That is, the nearly 20,000 smolts/EV of 2 g size produced by an original stock density of 110,000 fry/EV forecasts the production of nearly 2,000 adults/EV. This is consistent with our empirical observations of rearing limited sockeye salmon systems (equation 6) that produced 2,400-2,500 adults/EV. Moreover, the overall ocean survival estiamte derived from a comparison of equations 3 and 6, i.e., 2,500 adults/EV equals 11%. Finally, use of 2 g sized smolt populations throughout the calculations (outlined above) becomes the model for systems only capable of density-independent rearing. Thus, through validating empirical observations with experimental results, a set of equations emerge that are useful in estimating adult production levels from any stocking density based on a lake's euphotic volume, and the knowledge of density dependent versus density-independent juvenile rearing.

By modeling existing sockeye salmon production based on the above approach, we can now define 1) the enhancement approach most likely to result in a positive benefit, and 2) a realistic appraisal of expected adult production and the numbers of fry it requires which are especially useful in both planning and benefit/cost estimates.

EVALUATION

Approaches to Lake Manipulation: Fry Plants and Nutrient Enrichment

Since 1979, sockeye salmon rehabilitation and enhancement in Alaska has proceeded successfully along two fronts. The first is stocking or outplanting sockeye juveniles (0.2-0.3 g) into lakes to take advantage of a pre-existing excess in natural forage production. The second is enriching the lake environment with nitrogen and phosphorus to increase forage production for a high pre-existing level of juvenile recruits.

Briefly, results of the outplants from three different facilitites located in Southeast and Southcentral Alaska are summarized in Table 1. All lakes have a continuous record of successive annual outplants with values representing mean levels for resulting smolts and adults for the years on record (as indicated by the parenthesis). To date we have been successful at consistantly producing both smolts and harvestable adults through our hatchery program. Results of the fertilization of two lakes located in Southcentral Alaska are shown in Table 2. Our goal is to produce larger and younger smolts so that the freshwater and marine survival advantages of larger size can result in greater adult returns. For the equivalent numbers of spring fry planted in Leisure Lake, we have been successful at producing younger, larger, and more numerous smolts. No adult returns are available to compare as the first post-fertilization smolts left the lake in 1986. In Packers Lake, the response to the nutrients is similar in terms of larger, younger fish. However, Packers Lake serves as an example of the potential for error when having to use escapement numbers as an index to successful fry recruitment. Thus, perhaps the less numerous smolts observed in this one post-fertilization year.

Table 1. Synopsis of sockeye salmon fry plants from three State of Alaska hatcheries and the mean annual production as smolts and adults, realized for the number of years indicated in parentheses

Facility	Lake	Release years	Spring juvenile release (0.2-0.3 g) (mean)	Hatchery Smolts produced (mean)	Hatchery Adults produced (mean)
Crooked Creek	Tustumena	79-86	12,700,000 (8)	2,540,000 (6)	390,000 (4)
	Leisure	80-84	1,420,000 (5)	277,000 (5)	95,400 (3)
	Chenik[1]	78-81	450,000 (3)	--	46,000 (4)
Trail Lakes	Hidden	83-86	1,032,000 (4)	475,333 (3)	40,000 (1)
Beaver Falls	Bakewell/ Badger	85-86	525,000 (2)	120,000 (2)	

[1] 839,000 fry released in 1986 not included.

Table 2. Synopsis of changes in sockeye salmon smolt characteristics for Leisure and Packers Lakes resulting from the application of nitrogen and phosphorus to the epilimnion.

			Smolts				
			Age 1		Age 2		
Lake	Smolt year	Spring fry density (millions)	Size	Age (%)	Size	Age (%)	Total
Leisure:	Pre-fert. 1985	2.1	62 mm; 1.8 g	26	75 mm; 3.4 g	74	178,000
	Post-fert. 1986	2.1	84 mm; 4.8 g	60	110 mm;11.5 g	40	376,000
		Parent year adults					
Packers:	Pre-fert. 1983	13,000	96 mm; 7.0 g	5	104 mm; 9.4 g	92	246,000
	Post-fert. 1986	18,400	120 mm;16.0 g	63	140 mm;26.0 g	33	167,000

In review, we have found that the outplants of juvenile sockeye and the enrichment of sockeye nursery lakes have been beneficial and have produced adult pieces to the fishery. The most powerful tool may be the combination of both technologies on an intensive basis. However, the key to the success of either technology lies in its application to the proper environment and such recognition can only come from a proper pre-enhancement study.

Frazer Lake: An Analog for Sockeye Production at Turner Lake

In 1985, limnological studies were initiated on Turner Lake (Southeast Alaska) to define the existing rearing capacity for sockeye salmon juveniles. In particular, they were designed to refine the productive capacity equations presented earlier given the unique conditions of individual lakes. Turner Lake, presently a barriered system, is forecast to have the potential to produce 5.2 million smolts and ~568,000 adults when numbers of rearing juveniles match the ability of the lake to produce forage (Table 3). This forecast was based on an extensive evaluation of the productive potential of sockeye nursery lakes, located throughout Alaska, having euphotic zone depths ranging from 1.0 to ~23 m. Again, using the euphotic zone depth as a guide to fertility, lakes were found to be able to support stocking densities of ~110,000 spring juveniles/EV (either natural or from hatcheries or both) 23,000 smolts/EV of minimal (2 g) size, and 2,400-2,500 adults/EV (Koenings and

Table 3. Physical characteristics and measured sockeye smolt and adult production for Tustumena, McDonald, and Frazer Lakes compared to production levels predicted for Turner Lake [after the sockeye production model of Koenings and Burkett (1987)].

Lake	Surface area (km^2)	EZD (m)	Euphotic volume ($m^3 \times 10^{+6}$)	Smolts produced (millions)	Smolts per EV	Total return produced (number)	Adults per EV
Tustumena	295	1.2	354	8.10 (1981-86)	23,000	653,000 (1983-85)	1,850
McDonald	4.2	8	34	1.19 (1983-87)	35,000	121,000 (1980-85)	3,500
Frazer	16.6	15	249	--	--	617,370 (1985)	2,500
Turner	12.6	18	227	5.2 (predicted)	23,000	568,000 (predicted)	2,500

Burkett 1987). Thus, instead of using a passive feature (surface area) to normalize sockeye carrying capacity between lakes, a correction is made of inter-lake differences in productive capacity or fertility (Koenings et al. 1986, Lloyd et al. 1987). For example, Tustumena (Cook Inlet), McDonald (Southeast), and Frazer (Kodiak) Lakes are found to produce between ~1,900 and 3,500 adults per/EV. These lakes range in size of between 4.2 and 295 km^2 with euphotic zones ranging between 1.2 and 15 m. In contrast, surface area projections of adult production range between 2,200/km^2 (Tustumena), 29,000/km^2 (McDonald), and 37,000/km^2 (Frazer). Thus instead of a <2-fold range (per EV) based on lake fertility, a >17-fold range (per km^2) exists based on surface area. Similar comparisons can also be made for smolt production.

Within the lakes listed in Table 3, Frazer Lake comes closest to matching Turner Lake in terms of size, morphometry, typology, and previous history:

Feature	Lake	
	Frazer	Turner
Mean depth (m)	33.2	30.3
Surface area (km^2)	16.6	12.6
Euphotic Volume (units)	249	227
Water residence time (yrs)	2.0	0.8
Water clarity	Clear	Clear
Outlet	Barriered	Barriered

Prior to 1951, Frazer Lake (Kodiak Island) was sockeye free due only to an outlet barrier to adult access. A series of fish ladders provided access for adults produced from egg and fry plants that initiated the Frazer sockeye run.

Informative changes have occurred in the lake concurrent with the building of the run (Table 4). As potential spawners increased, the smolt sizes dropped, the number of macro-zooplankters decreased, and the zooplankton fauna changed. The decreases in smolt sizes and zooplankton density were expected as a consequence of density-dependent juvenile rearing, however, the change in zooplankter species composition indicated a change in lake fertility. That is, prior to the introduction of adults, Frazer Lake was very oligotrophic with a zooplankton population dominated by copepods (cladoceran to copepod ratio of 0.06). During this period (1965-70) nutrients contributed through carcass decomposition was low (136 kg), contributing only 8.2 mg P/m/yr to the lake, and adding only 0.24 mg P/m^3 to phosphorus levels of the lake. However, in recent years (1978-86), escapements have supplied 2,050 kg P which added 123.5 mg P/m^2/yr to the lake, and contributed 3.6 mg P/m^3 to the phosphorus concentration. Currently in the spring, the lake contains 3,000 kg P, a loading of 220 mg P/m^2/yr to the lake from all sources, and a spring P level of 5.5 mg P/m^3. Krokhin (1967) indicated the need for salmon carcasses to contribute 1.3 mg P/m^3 to lake P concentrations in order to stimulate fertility. Quite clearly this level was

Table 4. Changes in nutrient loading (phosphorus), zooplankton density and taxa ratio, and sockeye smolt sizes concommitant with increases in adult sockeye escapements since 1965 at Frazer Lake, Alaska.

Historical period	Mean sockeye escapement	Zooplankton ($No./m^3$)		Cladoceran to copepod ratio	Smolt sizes		Carcass-P		
		Macro	Total		(g)	(mm)	(kg)	($mg\ P/m^2/yr$)	($mg\ P/m^3$)
Early (1965-70)	17,030	10,620	14,110	0.06	30.8	152	136	8.2	0.24
Middle (1971-77)	83,385	3,590	6,996	0.17	19.3	127	672	40.5	1.20
Late (1978-86)	256,290	1,450	6,907	8.86	7.2	89	2,050	123.5	3.60

exceeded in Frazer only after the middle period (Table 4). Thus, during the more recent period the lake was annually undergoing bioenrichment which increased lake fertility. As a result the zooplankton fauna changed from totally excluding cladocerans (ratio of 0.06:1) to completely favoring them (ratio of 9:1) even though sockeye juveniles prefer to feed on cladocerans and tend to avoid the more agile copepods. Thus, adult fish provide two elements to nursery lake systems 1) potential recruits through successful spawning, and 2) carcass derived nutrients which increase lake fertility stimulating forage production for feeding sockeye juveniles.

Forage production is a key element to successful sockeye rearing in lakes. However, numbers and timing of seasonal abundances need be synchronized to fry entry into the lake. In addition, prey size must be greater than 0.40 mm, and forage should be available in the spring when fry enter the limnetic arena. In Turner Lake, the zooplankton are of two types, namely, the earlier peaking copepod <u>Cyclops</u> and the latter peaking cladocerans; <u>Bosmina</u>, <u>Holopedium</u>, and <u>Daphnia</u>. All are of a body-size capable of being consumed by sockeye juveniles. While densities are not as great as that found for the carcass enriched Frazer Lake, the higher range of densities found for Turner Lake do exceed the lower densities observed for Frazer and exceed the seven year range in densities found for Tustumena Lake (Table 5). In addition, the ratio (cladoceran:copepod) for Turner (0.34:1) is greater than that

Table 5. Summary of zooplankton population characteristics in Tustumena, Frazer, and Turner Lakes. Shown are the taxa composition (%), their ratio, and the range in spring and seasonal densities over the years listed.

		Zooplankton					
						Range of density (No./m^2)	
Lake	Station	Cladocera (A)	Copepods (B)	A to B ratio		Spring	Seasonal
Tustumena (1980-86)	B	0%	100%	0.0:1	A	0	0
					B	26,000-88,000	30,000- 62,000
Frazer (1985-86)	3	97%	3%	51.0:1	A	11,170-34,502	136,235-178,619
					B	529- 4,843	2,388- 5,308
Turner (1985-86)	2	26%	74%	0.34:1	A	10,422-11,335	27,654- 33,995
					B	62,830-97,513	77,882-106,470

found for the middle period at Frazer (0.17:1) and is greater than that at Tustumena (0:1), but lags behind that of Frazer in 1985-86 (51:1) (Table 2).

Overall forage production (quality and quantity) in Turner vastly exceeds that of Tustumena Lake, and lags behind Frazer Lake only in terms of cladoceran production. In terms of total macro-zooplankters Frazer Lake and Turner Lake are fairly comparable. Moreover, given the comparability of Turner and Frazer Lakes, the ability of carcass nutrients to increase the fertility of the nursery area of Turner Lake is certainly feasible. Without such nutrient input, the lake's natural fertility will have to drive forage production. As such, stocking densities will have to be closely evaluated to ascertain at what point forage production is unable to withstand annual increases in sockeye predation. This point may occur at fry densities below 110,000/EV unit. Indeed, Koenings and Burkett (1987) suggest that for nursery lakes lacking a means for adult access a stocking density of 54,000-55,000/EV unit may be more appropriate. Nonetheless, from an initial escapement of 6 adults in 1956 (Kyle et al. 1987), the sockeye run at Frazer Lake has grown to reach nearly 500,000 adults in 1980, 1981, and 1982 and to exceed 600,000 adults in 1985. Such levels of production are consistent with the EV of Frazer Lake (Table 3), and the modelled production of 2,400-2,500 adults/EV unit. Similar levels of adult production/EV unit are expected from Turner Lake especially if carcass nutrients can be replaced by additions of fertilizer.

Finally, we have used these results to establish stocking levels, expected smolt production, and adult pieces for a variety of lakes in Southeast Alaska (Table 6). Hence, we have developed an extremely powerful tool for the resource manager; one that can be refined with proper evaluation to further sustain and enhance sockeye salmon populations in Alaska.

Table 6. Lakes in Southeast Alaska and projected sockeye production levels when rearing-limited (after Koenings and Burkett 1987).

	Lake	Area (km^2)	1% light level (m)	EV (units)	Total[1] spring fry (millions)	Total[2] smolts (millions)	Total[3] adult pieces
1	Speel	1.7	--	--	--	--	??
2	Indian	2.2	8	18	2.0	0.4	45,000
3	Crescent	3.3	9	30	3.3	0.7	75,000
4	Lower Sweetheart	5.1	10	51	5.6	1.2	128,000
5	Redoubt	12.8	10	130	14.3	3.0	325,000
6	Chilkat	10.1	13	131	14.4	3.0	328,000
7	Turner	12.6	18	227	24.9	5.2	568,000
8	Heckman	1.6	7	11	1.2	0.3	28,000
9	Old Franks	2.5	5*	13	1.4	0.3	33,000
10	Neck	4.1	4	17	1.9	0.4	43,000
11	Patching	2.1	9	19	2.1	0.4	48,000
12	Hetta	2.1	15	32	3.5	0.7	80,000
13	Klawock	11.8	7	82	9.0	1.9	205,000
14	Woodpecker	0.7	10	7	0.8	0.2	18,000
15	Bakewell	2.9	6	17	1.9	0.4	43,000
16	Hugh Smith	3.2	6	20	2.2	0.5	50,000
17	Badger	2.1	13	27	3.0	0.6	68,000
18	McDonald	4.2	8	34	3.7	0.8	85,000
19	Reflection	3.0	15	45	5.0	1.0	113,000
20	Lake Grace	6.1	15(est)	92	10.1	2.1	230,000
21	Ella	6.2	15(est)	93	10.2	2.1	230,000
22	Manzanita	6.3	15(est)	95	10.5	2.2	238,000

*Mean depth
[1] 10,000 fry EV units
[2] 23,000 smolt EV units
[3] 2,500 adult EV units

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Statewide IHNV Control For Sockeye Programs

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I. Five Major Objectives

1. Establish a data base for IHNV in Alaskan sockeye.

2. Maintain and improve upon the sockeye policy regarding egg takes, incubation and rearing.

3. Yearly monitoring of IHNV prevalence and titers in broodstock.

4. Rapid diagnosis and containment of IHNV outbreaks within any salmonid species at production facilities.

5. IHNV Research.

II. IHNV Data Base

1. 352 entries encompassing 83 stocks from 1973 to present.

2. Represents over 20,000 virus assays.

3. Data Base average % prevalence IHNV = 32.3% geometric mean titer = 7.5×10^5.

4. All broodstocks have had detection of IHNV.

5. Prevalences range from 0 - 100% in ripe or post-spawning female fish.

6. Identification of high risk sockeye stocks.

III. Sockeye Policy in Effect - Prophylaxis

1. IHNV - free water source for incubation and rearing.

2. Stringent disinfection procedures regarding utensils, facilities, field clothing, personnel and external surfaces of broodfish.

3. Stringent external egg disinfection and water hardening in iodophor for 60 minutes after fertilization.

4. As much compartmentalization as possible of egg lots and fry during incubation and rearing phases.

IV. Yearly Monitoring of IHNV in Broodstocks

1. Routine samples of ovarian fluids from 60 ripe female fish used in the egg take. Reflects the amount of virus brought into the facilities.

2. Prevalence and titer is determined and added to the data base.

3. Ovarian fluids from post-spawned fish are used to establish a disease history on a new stock.

V. Fish Health Service to Diagnose IHNV Outbreaks in Fry

1. Representative samples of fry are submitted for at least two five fish pools for each lot or incubator of affected fish. Test may take from two to five days for positive cultures to appear (longer in subclinical cases).

2. Clinical signs of pre-emergence, hemorrhage, coagulated yolks, cephalic bumps and/or significant mortality are presumptive of IHNV. Fish are often destroyed if these signs occur to contain an outbreak <u>before</u> virus confirmation is completed.

3. Virus confirmation results in destruction of affected lots if not destroyed already.

VI. Research

1. Examination of IHNV titers and prevalence in selected broodstocks.

   a. Prevalence and titers in post-spawned vs ripe females.

   b. Variations of prevalence and titers in female ripe and post-spawned fish throughout the course of the run.

   c. Variations of prevalence and titers in female fish from year-to-year.

   d. Variations of prevalence and titers in male vs female fish-the role of males in IHNV transmission.

   e. Variations of prevalence and titers of seminal fluids vs organs in male fish. Which sample type to use for assays and what is the significance to the egg-take regarding virus levels in the hatchery?

   f. Results may not apply to all stocks.

2. Examination of the Enzyme Linked Innunoabsorbent Assay (ELISA) as a new method for more rapid and sensitive detection of IHNV.

A SUMMARY OF AUKE LAKE SOCKEYE SALMON RESEARCH RESULTS, CURRENT STOCK SITUATION, OUTLOOK AND MANAGEMENT CONSIDERATIONS

by

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April 1987

INTRODUCTION

Biological investigation of Auke Lake sockeye salmon began in 1961 and has continued on a more-or-less annual basis. Before 1973, studies focused on adult enumeration, spawning ground surveys and smolt emigration estimates. A limnological investigation of Auke Lake (Hoopes 1963) and a Master's Thesis (Bucaria 1968) on lacustrine growth of juvenile sockeye are exceptions. Much of the pre-1973 data lacks continuity and analyses are difficult. Data for the period 1961 to 1972 has been summarized by Taylor and Bailey (1972). Artificial enhancement studies were conducted using the 1973 and 1974 broods and Dewey (1977) reviewed all the sockeye data and summarized the material up to that time. This report summarizes the data through the 1986 adult migration.

ADULT ESCAPEMENTS

Adult sockeye salmon escapements to the Auke Creek system have been enumerated annually since 1963. Escapements during this 24-year period have ranged from 240 to 16,683 spawners. The mean escapement for the 1963-77 period is 7,982 spawners. Escapements have been in a declining trend since 1977 and mean escapement for the period 1978-86 is 2,573 spawners (Figure 1). Back calculation by age of sockeye adults returning to Auke Lake showed the decline of the stock began with the 1972-brood and has continued at least through the 1978-brood (Figure 2). It was also apparent that the 1968-brood was nearly a total loss, but it was not noticed in the adult returns because of the overlapping year classes common to sockeye. Sex ratios in the escapements have fluctuated moderately with the exception of 1974, when a 3.4 male to 1 female incidence occurred. Mean sex ratio for the 1963-83 period is 1 male to 1 female. Fecundity samples were taken in some years to determine the female length-fecundity relationship. Mean fecundity for Auke Lake sockeye salmon is 3,360 eggs. No fecundity samples have been collected since 1979 because of the declining escapements. Available data are summarized in Table 1.

Scale collections from adult sockeye salmon exist for all years from 1962 to 1986. Scale analysis has determined that five and six-year old adults predominate in the escapements. It is not uncommon to have large numbers of three-, four- and seven-year old sockeye in some runs at Auke Creek. Evaluation of the performance of a particular brood year is complicated because of the age combinations of smolts and adults. The age classes of sockeye observed at Auke Lake, using the 1976 brood as an example, is presented in Table 2. Approximately 50 percent of the returning females and 40 percent of the returning males are six years old (age 2.3, where the digit to the left of the period is the number of winters spent in freshwater and the digit to the right is the number of winters spent in the ocean). Spawners of ages 1.3 and 2.2 occur in significant numbers. A summary of the age structure of the escapements of Auke Lake sockeye is presented in Figure 3.

FRY RECRUITMENT

Spawning ground surveys have shown that the lateral tributaries to Auke Lake are utilized by sockeye. Lake Creek, the main lateral tributary, and the other small tributaries annually received about one-half of the total spawning escapement. It was assumed that the remaining one-half of the escapement utilized beach spawning areas within the lake basin, particularly the northern shores and the Lake Creek delta (Bucaria, 1968).

Sockeye fry recruitment estimates from the lateral tributaries are limited to Lake Creek for the years 1963, 1964, 1973 and 1974. Migrating fry were captured in fyke nets and enumerated in each of these years. The estimated recruitment in 1963 and 1964 was 134,666 and 118,129 fry, respectively. Recruitment from Lake Creek in 1973 and 1974 amounted to only a few hundred fry each year (Dewey, unpublished field notes). This variability in fry production can be attributed primarily to the unstable nature of Lake Creek during fall freshets with the resultant loss of seeded eggs, plus the dessication of the streambed during winter low streamflow periods.

The variability and relatively low numbers of sockeye fry recruited annually from Lake Creek suggest that other significant recruitment sources exist within the Auke Lake system. I believe it is reasonable to assume that in some years sockeye fry recruitment strength is dependent on fry production from beach spawning areas within the basin. No data are available to support this hypothesis.

From the above, it is apparent that survival from potential egg deposition (PED) to recruited fry for Auke Lake sockeye cannot be estimated from available data. Review of the literature would suggest that survival from PED to recruited fry of 11.25 percent is reasonable (Krokhin and Krogius, 1937; Foerster, 1938; Johnson, 1961; Foerster, 1968). This value has been used to calculate fry recruitment for Auke Lake sockeye (Table 1).

SMOLT PRODUCTION

Acceptance of the estimated survival from PED-to-fry permits additional survival estimates for the fry-to-smolt and PED-to-smolt life stanzas. Again, data are limited and survival estimates to the smolt stage will be limited to the 1972, 1973, 1978 through 1984 years. Accurate smolt migration estimates exist for 1964, 1975, 1976 and 1980 through 1986 (Table 4, Figure 4). Scale collections from Auke Lake sockeye smolts exist for the years 1964 and 1974 through 1986.

Survival from PED-to-smolt and fry-to-smolt in Auke Lake is considerably less than reported for British Columbia and western Alaska sockeye systems (Foerster, 1968). PED-to-smolt survival for Auke Lake is 0.03 to 0.3 percent as compared to the 1.5 to 3.0 percent for the Canadian and western Alaska stocks. Similarly, fry-to-smolt survival in Auke Lake varies between 0.1 and 3.1 percent as compared to the 20 percent for the Canadian and western Alaska stocks.

The production of smolts per female spawner has been estimated for the 1972 and 1973 and 1978 through 1984-brood years (Figure 5). The number of smolts produced per female spawner has ranged from 0.3 smolts for the 1979-brood to 31 smolts for the 1984-brood which includes only age I smolts that migrated in 1986. The estimate for the 1984-brood will increase when age II and III smolts migrate in 1987 and 1988. The production of 30 smolts per female spawner represents approximately 1% survival from potential egg deposition to smolt.

MARINE SURVIVALS

The marine survival of Auke Lake sockeye has been difficult to estimate because of incomplete counts of smolts in some years. Estimates for the 1972 and 1973 and 1977-79-brood years have ranged from 6.2 to 19.5% (Figure 6). Continued operation of the Auke Creek weir will permit accurate estimates to be made for future broods.

ARTIFICIAL ENHANCEMENT STUDIES

Studies at Auke Creek hatchery were conducted in the mid-1970's to enhance the runs of adult sockeye. These studies involved the 1973 and 1974 broods of Auke Lake sockeye and resulted in the release of 60,000 1973 brood and 54,000 1974 brood fry into Auke Lake. These fish contributed to smolt migrations in 1975 through 1978 and to adult migrations in 1976 through 1981. The enhancement studies were not fully evaluated, complicating the estimation of marine survivals for several brood years.

The decline of the Auke Lake sockeye run prompted the beginning of the present enhancement program. This program is intended to boost the return of endemic stock sockeye salmon to Auke Lake to about 5,000 fish. This would permit sufficient numbers of spawners into the system in order to evaluate spawning success in the lateral tributaries to Auke Lake. The enhancement program began with a year-long water quality study to assess the sockeye rearing capabilities of Auke Lake. Beginning with the 1986-brood, sockeye eggs will be incubated and the fry reared at Auke Creek hatchery. The fry will be marked by feeding a diet containing oxytetracycline (OTC) before their release in Auke Lake in late spring. Small numbers of migrating smolts will be sampled for OTC marks beginning in 1988.

POSSIBLE CAUSES OF DECLINE

The escapement of sockeye adults in 1986 was the second lowest ever observed at Auke Creek - only the 1985 escapement had fewer fish. In addition to the low adult numbers, the number of smolts has been in an apparent decline since the early 1970's. There are many hypotheses as to what happened, or is happening, and some of these are presented here in an attempt to resolve some questions.

1) The effects of commercial and sport fishing.

It is not likely that the Auke Lake sockeye have been affected by commercial or sport fishing. The Auke Lake sockeye usually appear in Auke Bay in late May or early June - well before the commercial sockeye fishery begins. The sport fishery in the early and middle 1970's removed 2,000 to 3,500 fish annually from the adult escapement. Sport fishing was restricted in 1976 and has been closed completely since 1980. The sport harvest of sockeye may have seriously reduced the reproductive potential of this stock, but there are no data to support this hypothesis.

2) Alteration of spawning habitat.

There has been an increase in the number of private homes on the north side of Auke Lake - near Lake Creek and the smaller tributaries used by sockeye - and domestic water demands may have affected water flows in sockeye spawning areas. Removal of gravel from submerged beaches on the Lake Creek delta may have disrupted water flows in that area and eliminated important spawning beds. There are no data to document water flow changes in the aquifer on the north side of Auke Lake, but the removal of gravel from the Lake Creek delta has been observed.

3) Limnological changes in Auke Lake.

There are approximately 50 residences on the north side of Auke Lake. Effluent water from domestic usage currently enters the Auke Lake system through drain fields or as untreated waste water. Waste water from the University of Alaska Auke Lake campus was discharged into Auke Lake before the completion of a local sewage system. It is possible that the combined waste water effluents caused a subtle change in the water chemistry of Auke Lake and disrupted the food supply of sockeye salmon juveniles. The 1985-86 water chemistry data from Auke Lake should be compared with samples collected in the 1960's.

4) Mortalities associated with work in the 1970's.

The work conducted on Auke Lake sockeye by Auke Bay Laboratory biologists in 1975 through 1979 has been directly blamed for the decline of the Auke Lake sockeye. There is no doubt that unacceptable mortalities of sockeye smolts did occur in some years at the lake-outlet smolt traps. However, I have reviewed all available data and have concluded that: 1) the sockeye runs were in a declining mode before the work began, 2) there was good marine survival of the smolts released during those years, and 3) the declining trend on Auke Lake sockeye continued after the return of adults resulting from downstream smolt migrations in 1975 through 1979. The declining trend is apparent if the 1973 brood sockeye are used for an example: 1) approximately 44,000 1973-brood smolts migrated downstream as age 1, 2 and 3 fish in 1975, 1976 and 1977, respectively, 2) these smolts experienced a 14% marine survival and 6,353 adults returned to Auke Lake, 3) these 6,353 adults produced fewer than 3,000 smolts, most of which left Auke Lake in 1980 at age 2.

5) Other causes.

Several other hypotheses have been suggested for the decline of the Auke Lake sockeye. These hypotheses include: 1) successive years of naturally occurring low egg-to-fry survival in Lake Creek, 2) superimposition of pink salmon eggs in Lake Creek and 3) disease related mortalities, such as IHN virus.

PRESENT AUKE LAKE SOCKEYE SITUATION

The escapement of sockeye adults in 1986 was the second lowest number ever observed at Auke Creek - only in 1985 were there fewer fish. For most years, smolt counts are not available and marine survivals cannot be estimated. Based on observations in the late 1970's and exact annual smolt counts since 1980, it appears that the production of smolts in Auke Lake has been in a decline since 1972. I believe the production of Auke Lake sockeye has been in a declining trend since the 1972 brood spawned, but because of the seven-year life cycle of sockeye, the decline was not apparent until the early 1980's. The release of hatchery-reared sockeye into Auke Lake in 1974 and 1975 supplemented the natural production of smolts and masked the decline of the wild sockeye until the last hatchery fish returned as adults in 1981. The escapements in 1977 through 1981 would have been smaller if not for the enhancement studies using the 1973 and 1974 broods.

The continued, annual operation of Auke Creek weir is essential to evaluation of wild stock production and enhancement projects. The annual enumeration of smolt and adult sockeye salmon is the only method of obtaining meaningful freshwater and marine survivals.

MANAGEMENT CONSIDERATIONS

In 1977 the existing spawner-smolt relationships for Auke Lake sockeye salmon were analyzed and an escapement of 7,500 to 9,000 spawners were justified (Dewey, unpublished field notes). Setting an adult escapement goal that will maximize smolt production and adult returns remains an issue. Past estimates of an adequate escapement, 5,000 to 7,000 spawners, were decided principally by speculation. A more precise method is needed and should be addressed using the Auke Lake data. I agree with the estimates presented by Dewey (1977) with the clarification that the escapement be based on the number of females. Based on the available Auke Lake data, an escapement of 3,500 to 5,000 females should produce 70,000 to 100,000 smolts. Assuming marine survivals on the order of 10%, the escapements should average 7,000 to 10,000 sockeye. However, if there has been a change or disruption in the basic productivity of Auke Lake, as it relates to sockeye, this issue should be addressed before initiating efforts to enhance the Auke Lake sockeye escapements.

Table 1. Auke Lake sockeye data summary for the brood years 1963 through 1983. Potential egg deposition (PED) is the product of mean fecundity and number of females. Fry estimates were based on potential egg deposition to fry survival of 11.25%. A return/spawner number less than one indicates poor production of a brood and the smolt/female ratio is an indication of survival in Auke Lake.

Brood Year	Total Escape- ment	Number Females	P.E.D. (millions)	Fry (millions)	Total Smolts	Survivals in Percent				Total Returning Brood	Return Per Spawner	Smolt/ Female Spawner
						PED to Smolt	Fry to Smolt	Smolt to Adult	PED to Adult			
1963	6,391	3,183	10.73	1.208					0.06	6,667	1.04	
1964	5,465	2,530	8.39	0.944					0.09	7,600	1.39	
1965	7,164	4,106	13.79	1.551					0.07	10,468	1.46	
1966	10,986	5,427	18.23	2.051					0.08	14,449	1.32	
1967	5,909	2,021	6.79	0.764					0.09	5,865	0.99	
1968	7,164	4,169	14.00	1.575					0.006	858	0.12	
1969	6,131	3,305	11.10	1.249					0.11	12,271	2.00	
1970	7,034	4,467	15.17	1.707					0.05	8,125	1.16	
1971	7,673	3,039	10.46	1,177					0.14	15,543	2.03	
1972	9,166	4,526	15.64	1.760	54,697	0.35	3.10	8.10	0.03	4,435	0.48	12.1
1973	8,259	5,072	17.82	1.988	44,929	0.25	2.26	14.1	0.04	6,353	0.77	8.8
1974	4,371	996	2.82	0.301					0.20	5,708	1.31	
1975	11,461	5,616	18.53	2.057					0.02	4,452	0.39	
1976	6,153	3,323	10.65	1,198					0.01	2,101	0.34	
1977	16,683	8,842	30.38	3.418	28,510	0.09	0.84	6.2	0.05	1,777	0.11	
1978	3,177	1,366	4.83	0.543	11,182	0.23	2.06	11.5	0.24	1,288	0.40	8.2
1979	6,072	3,011	9.90	1.114	1,486	0.03	0.10	19.5	0.003	302	0.05	0.3
1980	4,564	2,738	9.00	1.013	2,821	0.03	0.28					1.0
1981	4,089	2,658	8.74	0.983	16,718	0.19	1.70					6.2
1982	1,334	560	1.84	0.207	17,695	0.96	8.55					31.6
1983	1,805	939	3.08	0.347	8,800[1]	0.29	2.54					9.3
1984	975	480	1.61	0.181	15,000[1]	0.93	8.29					31.2
1985	240	120	0.40	0.045								
1986	952	476	1.59	0.179								

Table 2. Life cycle and ages of sockeye salmon at Auke Lake (1976 brood used as example). Ages are presented as the number of freshwater annuli to the left of the period and ocean annuli to the right.

		Smolt Age	Adult Age			Age At Maturity
1976	Spawning and incubation					
1977	Fry begin lake residence					
1978	Smolt migration	1.0				
1979	Smolt mig. and adult return	2.0	1.1			3
1980	Smolt mig. and adult return	3.0	1.2	2.1		4
1981	Smolt mig. and adult return	4.0	1.3	2.2	3.1	5
1982	Adult return			2.3	3.2	6
1983	Adult return			2.4	3.3	7

Table 3. Age class distribution of Auke Lake sockeye salmon in 1963-1977 spawning escapements.

Age Class	Sex	Mean (%)	S.D. (%)	Range
1.1	Males	1.2	2.3	0-06.6
	Females	1.2		
1.2	Males	9.8	16.0	0-35.8
	Females	8.5	16.6	0-47.9
1.3	Males	14.4	15.6	0-48.0
	Females	18.9	20.1	0-62.6
2.1	Males	8.8	12.1	0-50.0
	Females	0.4		
2.2	Males	19.9	18.5	0-54.5
	Females	13.5	9.4	0-24.3
2.3	Males	39.4	18.6	0-34.0
	Females	52.3	22.9	0-75.0
2.4	Males			
	Females	0	0	0
3.1	Males	0.8	1.0	0-02.3
	Females	0	0	0
3.2	Males	1.7	2.7	0-08.2
	Females	1.0	2.2	0-06.3
3.3	Males	4.0	6.5	0-17.8
	Females	5.6	8.5	0-24.8

Table 4. Counts of sockeye salmon smolts at Auke Creek, 1961 to 1984. All counts before 1980 should be considered incomplete estimates.

Year	Number of Smolts
1961	90,000
1962	———
1963	29,052
1964	62,389
1965	———
1966	———
1967	———
1968	35,737
1969	24,947
1970	———
1971	———
1972	3,388
1973	———
1974	15,399
1975	69,371
1976	51,972
1977	9,327
1978	7,855
1979	———
1980	25,299
1981	9,183
1982	1,719
1983	3,181
1984	20,248

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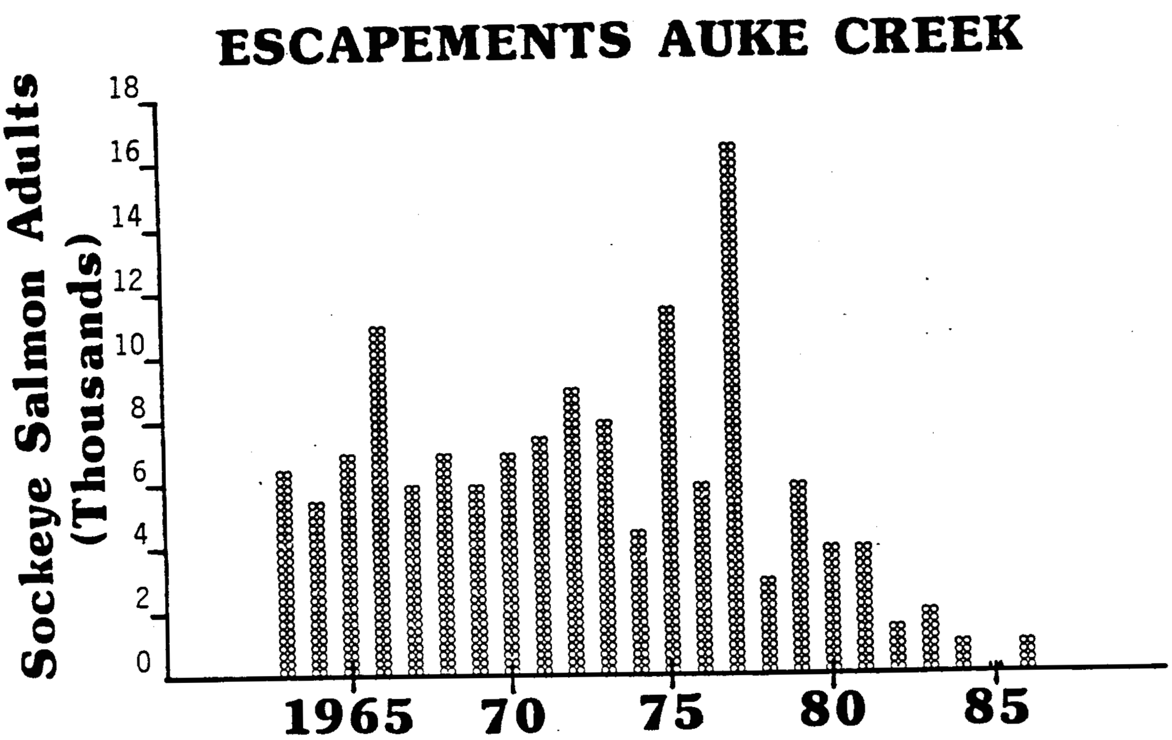

Figure 1. Escapements of sockeye salmon at Auke Creek, 1963 to 1986.

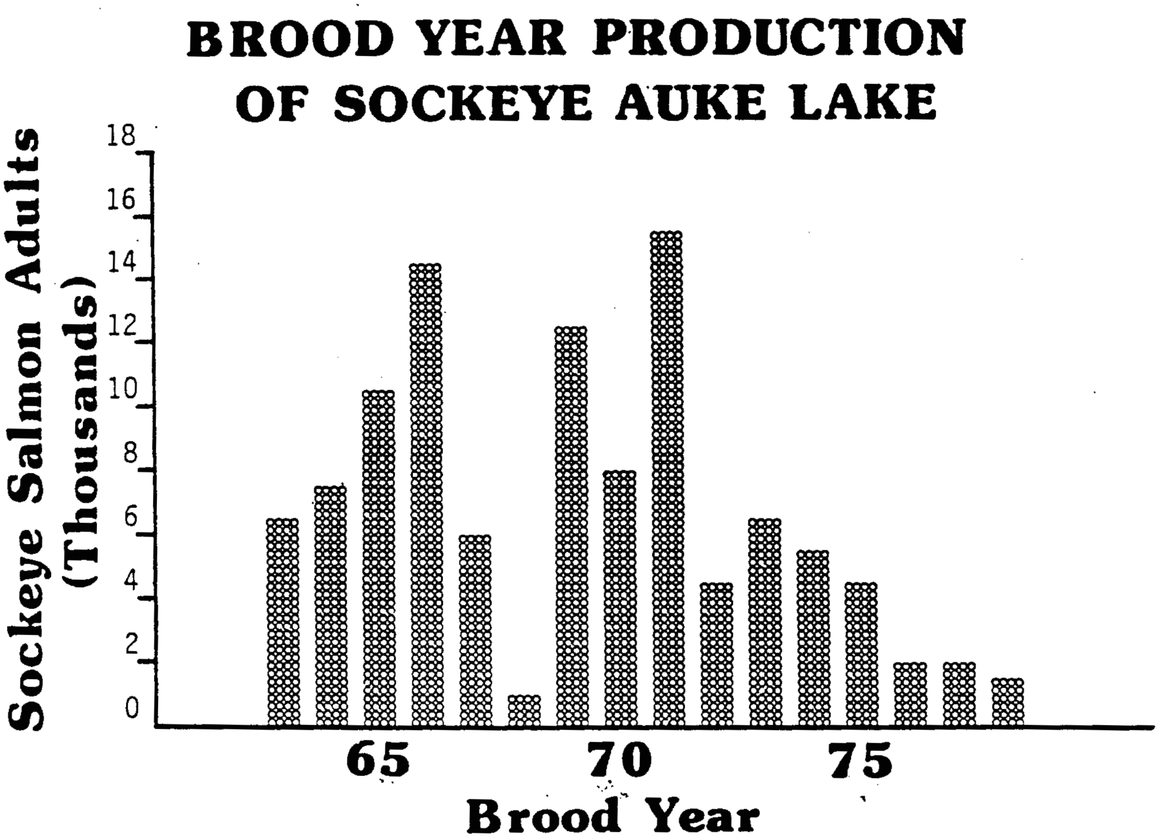

Figure 2. Total production of Auke Lake sockeye salmon for a particular brood year, 1963-1978.

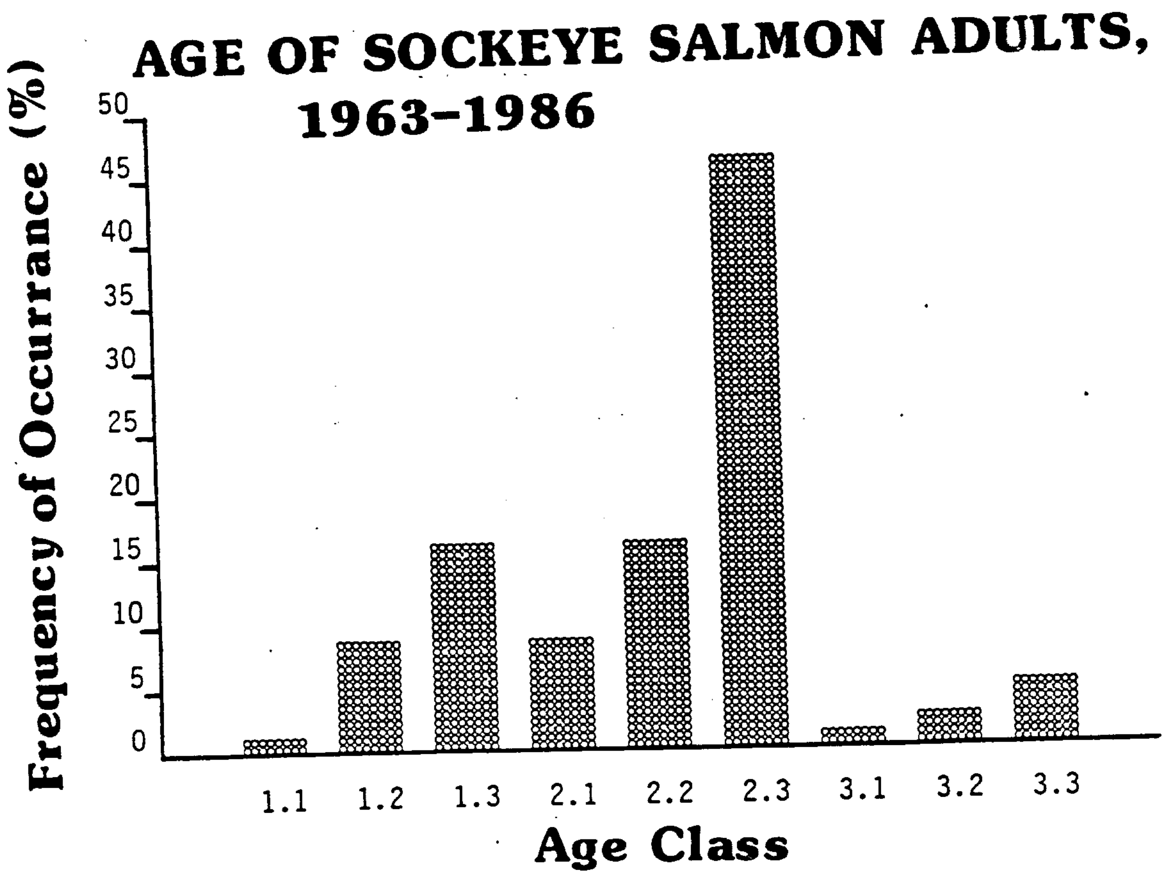

Figure 3. Mean age composition of Auke Lake sockeye salmon, 1963-
expressed as percent frequency of occurrence.

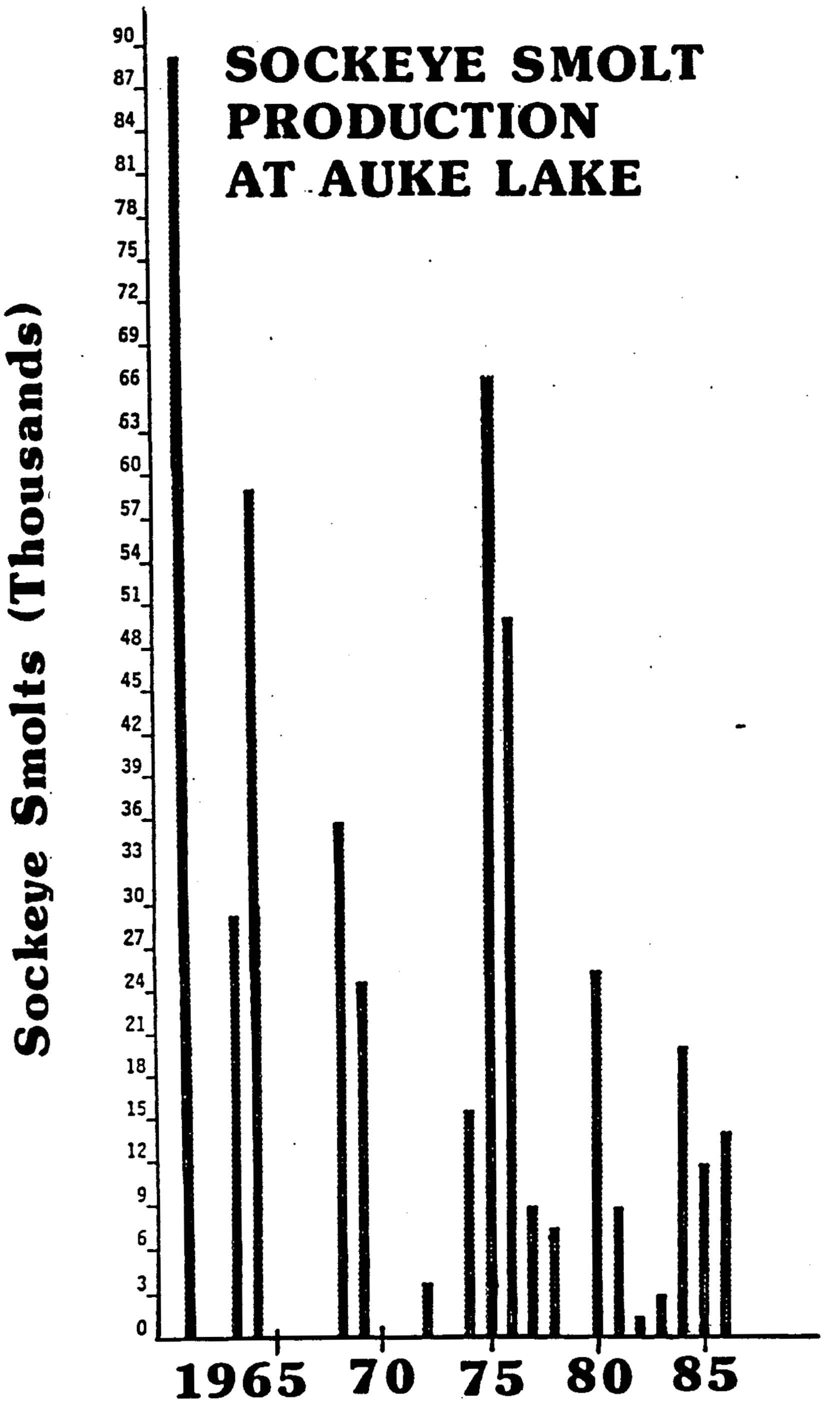

Figure 4. Sockeye salmon smolt production at Auke Creek, 1961-86. Estimations before 1980 are from fyke net operations, while those from 1980 are total counts as determined at Auke Creek weir.

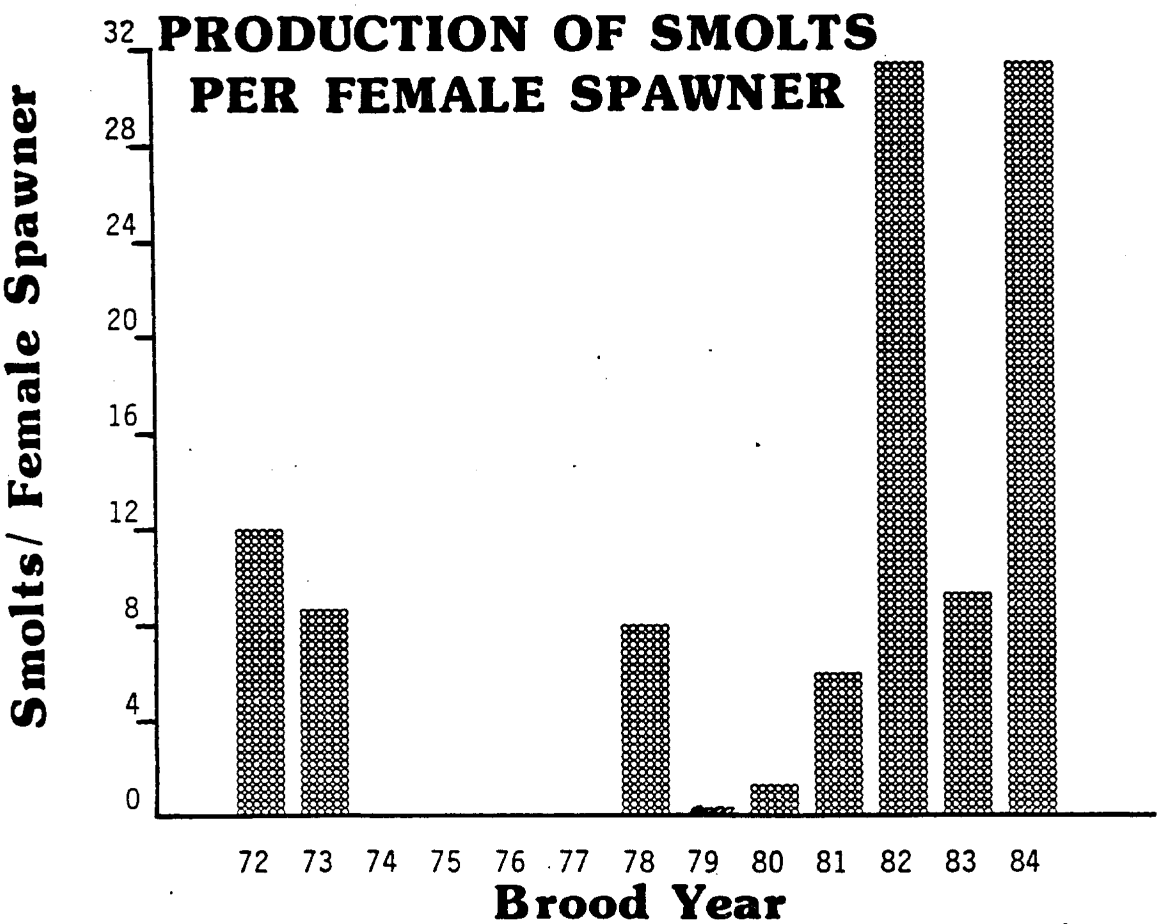

Figure 5. Total production of sockeye smolts produced by a particular brood year's spawning. (Expressed in number of smolts produced per female spawner).

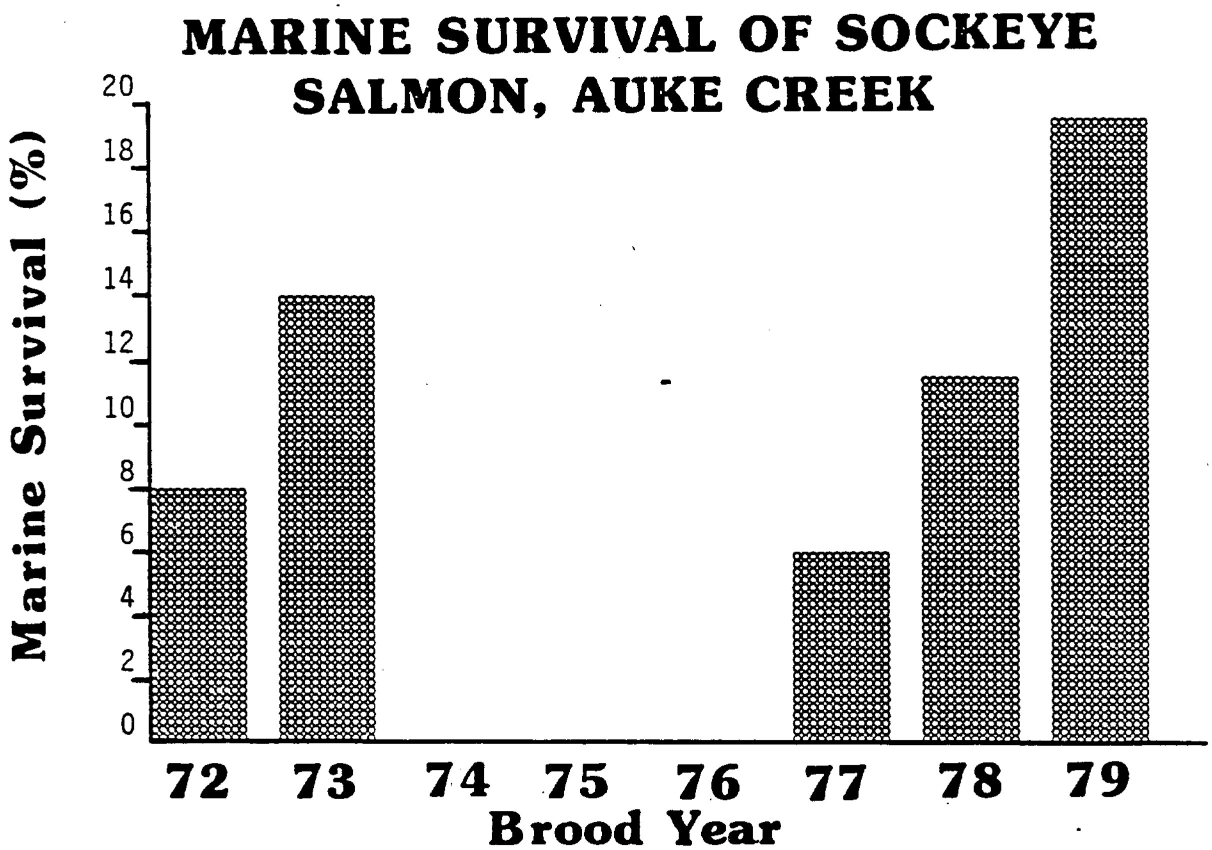

Figure 6. Marine survival of sockeye salmon at Auke Creek where returning adults have been assigned to their brood year and divided by the total number of smolts produced by that brood.

HATCHERY PRODUCTION/ENHANCEMENT

SUMMARY OF S.E. ALASKA F.R.E.D. DIVISION SOCKEYE SALMON REHABILITATION AND ENHANCEMENT PROJECTS

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<u>Hugh Smith Lake</u>:

The Hugh Smith Lake fertilization study began as a cooperative project with F.R.E.D. Division, the U.S. Forest Service, and Southern Southeast Regional Aquaculture Association in 1979. Pre-fertilization studies were conducted in 1979 and part of 1980. The fertilization phase began in 1980 and continued through 1983 with application during May through September each year. Post-fertilization studies continued in 1984 and 1985. Detailed limnological and fisheries studies to define trophic level changes as a result of fertilizer application were conducted, as outlined in FREDD lake fertilization project guidelines.

Findings based on data collected during the 1979 through 1985 study period showed definite increases in primary and secondary production and forage available for rearing sockeye salmon. Even though increases in forage occurred, no increases in sockeye salmon smolt production were observed. that is, size of smolt, growth rates, age composition, and survival of fry to smolt did not change during the study period.

These parameters, in fact, remained relatively constant over a wide (six-fold) variation in density of rearing sockeye juveniles.

This non-response of rearing fish to increases in food availability, a response to fertilization, and significant variations in rearing densities lead to the classification of Hugh Smith as a "density independent" lake. In fact, further studies revealed that temperature is limiting (B.2.a. lake). For some unknown reason, sockeye salmon fry at Hugh Smith Lake behaviorally key to a particular temperature isopleth throughout the year. This causes a limitation of fry growth rates and subsequent smolt size independent of fry density and/or forage availability. Thus, fertilization of Hugh Smith Lake, which functions as a density independent system, was not beneficial for enhancing sockeye salmon production.

Studies are continuing at Hugh Smith Lake to determine the feasibility of enhancing sockeye salmon production via introductions of hatchery incubated fry. Observed adult escapements have not provided adequate recruitment to fully utilize Hugh Smith's rearing habitat. These low escapements are due to continued high harvest levels of these stocks in existing commercial fisheries. Plants of 278,000 and 225,000 fry were made in 1986 and 1987, respectively. These fry were from eggs taken from Hugh Smith Lake and incubated at FRED Division's Beaver Falls Hatchery in Ketchikan.

McDonald Lake:

The McDonald Lake fertilization study began as a cooperative project with FRED Division, the U.S. Forest Service, and Southern Southeast Regional Aquaculture Association. Pre-fertilization studies began in 1980 and continued until 1982 when fertilizer application began. Fertilization has continued through 1986 and is planned for 1987.

Detailed limnological and fisheries studies at McDonald Lake have shown definite increases in primary production and limited increases in secondary production. No significant observed changes have occurred in sockeye salmon fry growth rates, smolt sizes, or age composition until 1986 when growth rate increased and mean size of 1986 smolt was larger than previous years.

Total production has been at a very high level. Rearing densities have been very high with total numbers of outmigrant smolts ranging from 1 to 3 million. Since survival to smolt has remained relatively high during the five years of fertilization, and smolt size increased in 1987 with increased fertilizer additions in 1986, it can be speculated that fish production is being artificially maintained at an elevated level. It can also be argued that other environmental factors are at play; we have no unequivocal data. Nevertheless, adult production based on escapement into the lake averaged 80,000 during eight years for which data were available prior to fertilization. The first year for returns that received full benefit of fertilization was 1986 when 20,000 adults escaped to the lake. To the best of our knowledge, commercial fisheries exploitation of this stock has remained constant. Further, our data show an asynchrony between maximums of zooplankton standing crops (fall) and mid-May fry emergence that is being brought to coincidence by nutrient enrichment.

Present plans call for continuation of fertilizer application and monitoring production at all trophic levels. Coded wire tagging of McDonald lake sockeye salmon smolts has identified the stock as a significant contibutor to the District 106 gillnet fishery. Due to the importance of the lake in producing fish for existing fisheries, and some evidence that fertilization is maintaining a stable production at a high level, fertilization should be continued. This continuation should depend upon available funding levels and future evaluation of production from the system.

Badger Lake Sockeye Salmon Fry Planting Project:

Badger Lake is the upper lake in the Bakewell Lake drainage. As part of a program to more rapidly develop a sockeye salmon run back to the system after reconstruction of the Bakewell Creek fishway, fry plants were initiated at Badger Lake.

Studies were initiated in 1984 to define the potential of Badger Lake as rearing habitat for juvenile sockeye salmon. The lake was planted with 556,000 sockeye salmon fry in June of 1985, and 515,000 in June of 1986. These fish were from eggs taken from Hugh Smith Lake and incubated at the FRED Division Beaver Falls Hatchery. The initial plants had an excellent survival to smolts (25%) and grew nicely (mean smolt size of 80 mm).

The projected returns from these initial plants are 20,589 adults during the period 1988 through 1989.

Northern Southeast Area:

The inclusion of the northern Southeast area into the lake enrichment program occurred in 1980 - 1981 with the implementation of a lake enrichment feasibility study at six sockeye salmon nursery lakes in this area. The results of this study indicated that Falls and Redoubt Lakes were the best candidates for inclusion into the program.

Detailed pre-enrichment studies were initiated at Falls and Redoubt lakes in 1981 and 1982, respectively. Each lake was investigated for two years prior to fertilizer application in order to document the existing fish production (in-lake rearing fry, smolt, and adults) and limnological (physical, chemical, and primary and secondary biological production) characteristics.

Falls Lake:

Fertilizer applications were initiated during 1983 and continued through 1985. Fertilizer was applied at varying rates and intervals between May and September of each year.

The fertilizer applications increased phytoplankton production. This coincided in 1983 and 1984 with increased densities in the zooplankton community. During 1985, the zooplankton densities remained at the relatively low pre-fertilization level throughout the fertilizer application period even though 1985 phytoplankton levels were the highest for each of the three years of fertilization.

Although the age composition and total smolt emigration numbers remained relatively stable, the data indicate that there was a significant increase in smolt size (length) between the pre-fertilization years and the fertilization years. Since smolt size has been identified as having a direct affect on adult marine survival, we can, therefore, surmise that this increase in size will have a positive affect on adults. Since the adult sockeye salmon returning to Falls Lake are predominately 5 and 6 year old fish (82%), the adults produced from the 1982 brood (the first brood affected by the fertilizer applications) should begin returning to the lake in significant numbers during 1987 and 1988. The majority of adult fish produced (as smolts) during the fertilization years will return to the lake from 1987 until 1992.

The original plan for the Falls Lake project stated the intention to continue monitoring this lake after the cessation of fertilizer application. However, the current budget climate within the FRED Division forced the shut-down of this project. Interest remains in continuing the support of the efforts of the U.S. Forest Service to monitor the adult escapement to Falls Lake relative to the evaluation of its fish ladder project at this site. The information generated from this monitoring would also be useful in evaluating the adult production resulting fromthe fertilizer applications made during 1983 - 1985.

Redoubt Lake:

Fertilizer applications were initiated during 1984 and are projected to continue through two life history cycles (1998) for the sockeye salmon at this project site. Fertilizer has been applied to the lake at various locations, application rates, and intervals between May and September during 1984 through 1986.

The Phytoplankton data for 1984 and 1985 show an increase for all sampling sites. This increase coincided with an increase in observed zooplankton densities. Sample and data analyses for 1986 are still underway.

Quantitative smolt sampling was included in this project since its initiation in 1982. Due to the configuration of the lake outlet and the discharge levels from the lake, numerous smolt capture methods have been attempted to generate an estimate of total smolt emigration. All of these methods have proven unsuccessful in generating a quantitative estimate of the total smolt emigration from the system. The most aggressive approach to date will occur in 1987. Should this effort fail, we will turn to hydroacoustic estimates and forget about smolt fences.

Age and size of smolts observed since 1982 indicate no specific trends in changes to age composition, but a significant increase was observed in smolt size (length) between the pre-fertilization and fertilization treatment years. This increase in smolt size can be directly correlated to an increase in marine survival rates, thereby increasing the number of adults expected to return.

The adult sockeye salmon produced from this system are predominately 5 and 6 year old fish (88%). Therefore, the adults produced from the 1983 brood year (first brood affected by fertilizer application) should begin returning to the lake in significant numbers during 1988 and 1989. Relative to the completed fertilizer applications, adults effected by the fertilizer application will be returning to this lake until 1992.

Using the fisheries and limnology data base generated from this project, Redoubt Lake can be categorized as a density independent system due to the small forage food base and underutilized rearing habitat. This lake has the potential to benefit from the continuation of the fertilization program and from artificial plants of sockeye salmon fry. Continuation of the project is strongly linked to delivery of hatchery fry to the system. Otherwise, there simply will not be sufficient numbers of salmon fry present in the lake to take advantage of the additional forage produced from enrichment. The current plans for this project are to continue applying fertilizer to the lake and to initiate a fry stocking project as soon as possible.

NSRAA's Sockeye Program
Bruce Bachen
April 17, 1987

Northern Southeast Regional Aquaculture Association (NSRAA) is placing a high priority on the production of sockeye salmon particularly in gill net areas. Sockeye enhancement activities have been limited to technology development of remote incubation techniques and pre-enhancement study of potential sites. Northern Southeast is currently incubation-limited since there are no sockeye facilities in this area to support sockeye projects.

With this limitation in mind, NSRAA has been developing two types of on-site incubators.

1) In-lake incubators. The primary considerations in designing this type of incubator are: a) keep egg density low to allow passive diffusion to take care of oxygen and ammonia transport; b) compartmentalize eggs so that if fungus is established, its impact will be limited to the few eggs that are in direct contact; c) on-site incubation may lower the risk of spreading IHN; d) this type of incubation may be suitable for smaller lakes and allow a larger number of projects to be initiated. Results to date are encouraging with survival from green egg to alevin typically in excess of 90%. We are completing the second year of testing and concentrating on selecting a design that can be produced quickly and inexpensively.

2) Incubation boxes. We have developed a design for remote, unattended incubation boxes using groundwater supplies. Each 4'x8'x2' (deep) box will hold at least 200,000 eggs. So far all development has been done with chum, but results should be applicable to late spawning sockeye stocks that are adapted to groundwater.

Pre-enhancement studies are necessary to document potential of lakes to produce sockeye. We worked on Turner Lake in 1985, focussing on evaluation of fish populations and evaluating the potential conflicts that might occur between resident trout and introduced sockeye. ADF&G is currently preparing a report identifying preferred options for using Turner lake for sockeye production and NSRAA remains a strong supporter of the project.

A cooperative sockeye study is being initiated for Mosquito, Chilkat and Chilkoot lakes in May 1987. ADF&G (FRED & COMFISH) and NSRAA are paying for the work. NSRAA is interested in identifying the maximum production capacity of the lakes and seeing the lakes produce at that level.

During the next field season, NSRAA will be identifying potential sockeye projects for review and approval by its board of directors next winter.

SOCKEYE ENHANCEMENT BY THE SOUTHERN SOUTHEAST REGIONAL AQUACULTURE ASSOCIATION

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Introduction

The Southern Southeast Regional Aquaculture Association (SSRAA) has been involved in sockeye salmon enhancement since 1979. The initial efforts were focused on lake fertilization in a cooperative approach with the Alaska Department of Fish and Game (ADF&G). However, after several years effort the project was discontinued in 1985 because the results did not show the project to be cost effective. ADF&G turned their attention to lake planting of fry which had been successful in south central Alaska. SSRAA turned their attention to a more traditional hatchery approach.

Hatchery rearing of sockeye is not new. The earliest salmon hatcheries in Alaska during the late 1890's were sockeye hatcheries. For various reasons, nearly all sockeye hatcheries on the west coast had closed by the late 1930's. Modern hatchery techniques and improved pelleted feeds allowed hatchery rearing of Pacific salmon to become successful by the mid-1960's. These developments are the basis for the hatchery rearing of salmon today - except sockeye.

The primary limitation to sockeye rearing is due to a virus which is carried in nearly all adult sockeye populations. This virus causes a disease called Infectious Hematopoietic Necrosis (IHN) and, when it occurs, mortality can exceed 90%. The risk of IHN is extremely high unless certain precautions are taken.

The current scientific evidence indicates that the IHN virus is shed by spawning adults and this virus can survive for many months in cool water. The virus which is in the water can infect susceptible fry causing disease if the exposure is high (horizontal transmission). Also, eggs may be contaminated from adults shedding the virus. Eggs which have high exposure to the virus may result in infected fry when they hatch (vertical transmission). However, if the virus can be removed from the eggs and if no virus is in the water, sockeye can be reared successfully using normal hatchery techniques. This has been done experimentally on a number of occasions and the practice is now being extensively used on the Pacific coast.

The key to successful rearing of sockeye, then, is to avoid contact of the fry with the IHN virus. This is accomplished in several ways. The most important is to have a water supply that does not contain sockeye salmon, or any other fish, which can shed the virus into the water. Another way is to break the adult to fry cycle by disinfecting the eggs with chemicals which will destroy the virus. Because disinfection may not be completely effective and effectiveness is somewhat dose dependant, further precaution can be taken by testing each adult fish for virus, and discarding all eggs which come from high virus shedding fish, followed by disinfection. Even further precaution can be taken by incubating the eggs from each spawning pair as a family unit in isolation, separated from other eggs, with an independent water supply. If all other precautions fail, the disease would be isolated to just one group of fry which can be destroyed before the other fry are exposed to the virus. This is the basis for SSRAA's sockeye program.

Stock Selection

The following sockeye stocks were considered for the brood: Hugh-Smith, McDonald, and Karta. Initial screening indicated that the incidence of IHN in the Hugh-Smith stock was very high. The McDonald stock enters Behm Canal in late July and early August, the fish hold in the estuary until late August, and then move into the McDonald Lake system in September when spawning occurs. The fish, when they enter fresh water, are already water marked and not the highest of quality. The Karta sockeye enter fresh water in late June and early July, hold in Salmon Lake, then move into the streams to spawn in late August. In all cases, Southeast Alaska sockeye spend one to two years in a lake and migrate to the ocean as one check or two check 3 gram smolts (range 1 - 5 gram).

Several criteria were considered in selecting the brood source. First, it was desirable to have fish enter the commercial fishery early in the season. ADF&G management has limited the early commercial fishing seasons in late June and early July due to the U.S./Canada treaty to minimize interception of Canadian sockeye stocks. Early returning fish would provide for early fishing opportunity and extend the fishing season. Second, if most of the fish had to be harvested in the terminal area, the fish should arrive in the terminal area in prime condition.

Third, some of the adults would have to be harvested by SSRAA for cost recovery. Therefore, the fish should be harvested in the best possible condition. In order to keep harvest costs to a minimum, it would be desirable to have the fish enter fresh water in prime condition.

Fourth, in order to keep rearing costs to a minimum, it would be desirable to release the fry in their first year as zero check smolts. Studies in other sockeye systems indicate that if fry reach a 3 gram size in their first year they will migrate as zero-check smolts. In order to maximize the potential of obtaining a zero check smolt, it was desirable to obtain an early spawning broodstock in order to get the maximum growth potential before the next spring.

Fifth, the broodstock should have a low incidence of IHN virus in order to reduce the risk of disease transmission and to avoid excessive destruction of eggs due to the culling procedure.

Using the above criteria, the Karta stock was selected as the brood source and the donor source was McGilvery Creek. About 150 families (150 females and 150 males) were collected in 1985 and 1986. The fish were collected during the third week of August and were among the first spawning fish available. The fish were collected by snag gear and the gonadal products were collected from each individual fish and transported to Ketchikan on ice using standard remote eggtake procedures. Sanitary precautions were taken in obtaining the gonadal products in order to prevent cross contamination at the brood location. This procedure will be repeated for at least two more years.

Fish Culture Techniques

The objectives of the fish culture aspect were to rear the fry free of IHN and to release a zero check smolt. Another objective was to keep the costs to a minimum until the project proved successful. Beaver Falls was selected because ADF&G already had a sockeye project on site and because the water supply came from Silvis Lake. Silvis Lake is a barriered lake with no access to anadromous fish. Several species of salmon had been reared at this site with no evidence of IHN. It was assumed the water supply was free of IHN virus, thus meeting the most important criteria of the project. Also, the site was on the Ketchikan road system and, therefore, reduced operational costs because it could be operated from the Whitman Lake Hatchery. The major problem with Beaver Falls is the cool water supply in the winter and this would work against the zero check objective.

IHN has not been detected after two years of operation. The preventative measures have worked. Each adult fish was tested for virus and the eggs disinfected after fertilization and incubated in individual incubators with separate water inlets and outlets. Those families that had either parent with high shedding of virus were destroyed. The eggs were disinfected a second time after they reached the eyed stage and the fry were held in their individual incubator until they were ready to be fed. The fry were again tested for virus before they were placed into small rearing tanks to commence feeding. Again, the rearing tanks were isolated with separate water supplies and no more than five families were placed in the rearing tank. Personnel were trained to use strict sanitary techniques.

Experience by SSRAA with other salmonid species has shown that fish grow much faster once they are placed in marine netpens. The advantages are in more favorable water temperatures, some natural food, and some osmoregulation advantages. However, the ability of sockeye salmon to thrive in salt water under a 3 gram size was unknown, but there was some evidence that sockeye could tolerate salt water at a 1 gram size. SSRAA conducted tests in 1985 which showed that 0.7 gram sockeye tolerated salt water but blood sodium levels indicated they were not osmoregulating properly. However, 1.5 gram sockeye did exceptionally well in salt water. A goal was then established to have the sockeye at a 1 gram size or larger by early June.

The first release of sockeye at Beaver Falls occurred in 1986. The spring of 1986 was cool and growth was slow. The sockeye were placed in net pens on June 30 at a 1.4 gram size and were released eleven days later on July 11 at a 2.2 gram size. This was later and smaller than our goal. However, the fish responded very well to salt water and about 100,000 smolts were released in excellent condition. The survival of these fish will not be known for several years, but we believe that the best results will not be obtained until the typical release size is over 3 grams by mid-June. The next group is due for release in 1987 and, to date, they are larger than the first groups.

There are two approaches that are needed to help assure a target of 3 grams by mid-June. One is to obtain eggs earlier to take advantage of the warm fall temperatures. This may be done by hormone injection of the adult fish and by shortening the photoperiod. Tests are scheduled in 1987 to evaluate this approach. Second, is to warm up the water after the fry hatch. Using energy to heat water is cost prohibitive, but we plan to install a heat exchanger to be submerged in George Inlet at Beaver Falls. The marine water temperature is always warmer than the fresh water during the winter. Although there is a capital expense involved, the operational expense is small. By using these two approaches, we will help assure our goal of 3 gram sockeye smolts by mid-June.

Future Plans

The current plans of SSRAA are to use Beaver Falls only as a broodstock site and remotely release the main production at other sites for cost recovery and for terminal wipe-up fisheries. The first return of adult fish is expected in 1989, but some fish may be available in 1988. Plans now are to increase the egg incubation capacity at Beaver Falls up to 5 million eggs by the summer of 1989. It is assumed that the capital investment will be about $1.5 million and the annual operating costs will be about $150,000 giving an annual total cost of $250,000 if amortized over 15 years.

The adult survival rate will not be known for several years, but we are assuming a 6% smolt survival. This is conservative according to ADF&G assumptions. Based on this assumed survival rate, an annual release of 300,000 smolts should provide sufficient returning adults for expansion to the 5,000,000 eggs goal (Table 1). Releases of 1,000,000 smolts for cost recovery, such as Shrimp Bay, should provide an annual revenue of over $200,000 (Table 2). This should cover all operational costs.

Assuming an 80% egg to smolt survival, this should provide an annual release of 2,700,000 smolts for a terminal wipe-up fishery. This fishery would provide a value of $500,000 in the terminal area, another $250,000 in the common property fishery, and another $150,000 from the releases at Shrimp Bay and Beaver Falls. The total common property harvest should be about $1 million.

The program as outlined in this paper may result in a broodstock which is free of IHN virus because the adult-to-fry transmission cycle may be broken. If this occurs, then there is potential of stocking barren lake systems with sockeye without the risk of spreading IHN virus to new localities. Also, the above analysis shows that the project can be very cost effective and may need expansion. If one assumes that an expansion is desirable after five years, then the program can be modified to provide revenue to build a 20 million egg facility. Table 1 shows that the program could be expanded by 1993 and that a 7 million smolt release would provide over $1.3 million annually by 1996. The program could potentially pay for itself.

Compared to other species, sockeye are a good investment if all the above assumptions are correct. Table 2 compares the cost-to-benefit of sockeye compared to chinook, coho, or steelhead, all of which compete for freshwater space. The value of one raceway of sockeye may be worth over $500,000 compared to the same raceway production of $87,000 for chinook, $186,000 for coho, and $60,000 for steelhead.

The advantages of this program, if successful, are that annual operating cost are reduced by not having to take eggs remotely; the potential exists to stock barren systems without increasing the risk of spreading IHN virus; the fish will extend the early commercial fishery by giving opportunity in late June; the fish will be tagged and the common property fishery could be extended by allowing an add-on to the existing quota; should the fish end up in the terminal area, they could be harvested in good condition; terminal areas can be selected to avoid conflicts with wild salmon stocks, thus avoiding terminal management complications; the program can pay for itself through cost recovery; and the program would allow cost recovery of high quality fish which avoids conflict with fishermen.

TABLE 1

FIVE YEAR PLAN

WHITMAN/BEAVER FALLS SOCKEYE

01-Apr-87

YEARS OF RETURNS		1988	1989	1990	1991	1992	1993	1994	1995	1996
TOTAL RETURN		0	0	150	2,925	8,700	85,725	90,000	106,500	403,500
0s		0	0	150	2,925	8,700	85,725	90,000	106,500	403,500
YEARLING		0	0	0	0	0	0	0	0	0
TOTAL US	0s	0	0	41	790	2,349	23,146	24,300	28,755	108,945
	YEARLING	0	0	0	0	0	0	0	0	0
SEINE	0s	0	0	30	585	1,740	17,145	18,000	21,300	80,700
	YEARLING	0	0	0	0	0	0	0	0	0
GILLNET	0s	0	0	8	146	435	4,286	4,500	5,325	20,175
	YEARLING	0	0	0	0	0	0	0	0	0
OTHER	0s	0	0	3	59	174	1,715	1,800	2,130	8,070
	YEARLING	0	0	0	0	0	0	0	0	0
BROODSTOCK	0s	0	0	0	0	0	0	0	0	0
	YEARLING									
TERMINAL	0s	0	0	105	2,048	6,090	60,008	63,000	74,550	282,450
	YEARLING	0	0	0	0	0	0	0	0	0
CANADIAN	0s	0	0	5	88	261	2,572	2,700	3,195	12,105
	YEARLING	0	0	0	0	0	0	0	0	0

RELEASES

YEARS OF RELEASES	1986	1987	1988	1989	1990	1991	1992	1993	1994
# 0s	0	0	50,000	75,000	1,500,000	1,500,000	1,500,000	7,000,000	7,000,000
# YEARLING	0	0	0	0	0	0	0	0	0

FINANCIAL ANALYSIS $VALUE

YEAR		1988	1989	1990	1991	1992	1993	1994	1995	1996
TOTAL ALL		$0	$0	$729	$14,216	$42,282	$416,624	$437,400	$517,590	$1,961,010
TOTAL US	0s	$0	$0	$225	$4,388	$13,050	$128,588	$135,000	$159,750	$605,250
	YEARLING	$0	$0	$0	$0	$0	$0	$0	$0	$0
SEINE	0s	$0	$0	$180	$3,510	$10,440	$102,870	$108,000	$127,800	$484,200
	YEARLING	$0	$0	$0	$0	$0	$0	$0	$0	$0
GILLNET	0s	$0	$0	$45	$878	$2,610	$25,718	$27,000	$31,950	$121,050
	YEARLING	$0	$0	$0	$0	$0	$0	$0	$0	$0
OTHER	0s	$0	$0	$0	$0	$0	$0	$0	$0	$0
	YEARLING	$0	$0	$0	$0	$0	$0	$0	$0	$0
TERMINAL	0s	$0	$0	$504	$9,828	$29,232	$288,036	$302,400	$357,840	$1,355,760
	YEARLING	$0	$0	$0	$0	$0	$0	$0	$0	$0

ASSUMPTIONS

	0s	YEAR.
SURVIVAL 0s	6.00%	
SURVIVAL YEAR.	6.00%	
AGE COMP.	0s	YEAR.
3YR.	5.00%	5.00%
4YR	90.00%	90.00%
5YR	5.00%	5.00%
CONTRIBUTION	0s	YEAR.
SEINE	20.00%	20.00%
GILLNET	5.00%	5.00%
OTHER	2.00%	2.00%
TOTAL US HAR.%	27.00%	27.00%
TERMINAL%	70.00%	70.00%
CANADIAN%	3.00%	3.00%
TOTAL	100.00%	100.00%

ASSUMPTIONS

		PRICE $	AVE Lbs/FISH
SEINE	0s	$1.00	6
	YEARLING	$0.00	6
GILLNET	0s	$1.00	6
	YEARLING	$0.00	6
OTHER	0s	$0.00	6
	YEARLING	$0.00	6
TERMINAL	0s	$0.80	6
	YEARLING	$0.00	6

TABLE 2. WHITMAN LAKE PRODUCTION VALUES/RACEWAY FOR FOUR SPECIES

	CHINOOK YEARLINGS	COHO YEARLINGS	STEELHEAD 1 YEAR	STEELHEAD 2 YEAR	SOCKEYE
RACEWAY DENSITY 6356 ft	.5 lb/ft	1 lb/ft	1 lb/ft	1 lb/ft	.5 lb/ft
RELEASE SIZE IN FRESH WATER	30g	15g	30g	50g	1g
NET PEN RELEASE SIZE SALTWATER	50g	25g			2.5g
# FISH/RACEWAY	48,152	192,000	96,303	57,594	1,440,000
EST. SURVIVAL	6.0%	10.0%	5.0%	10.0%	5.0%
# FISH	2,889	19,200	4,815	5,759	72,000
% CPF	60.0%	75.0%			75.0%
# FISH	1,733	14,400			54,000
EST. AVE. SIZE CPF	18 lbs.	8 lbs.			7 lbs.
EST. VALUE/POUND	$2.00	$1.25			$1.25
EST. VALUE TO CPF	$62,402	$144,000			$472,500
%TERMINAL	40.0%	25.0%	100.0%	100.0%	25.0%
# FISH	1,156	4,800	4,815	5,759	18,000
EST. AVE. SIZE	22 lbs.	11 lbs.	6 lbs.	6 lbs.	7 lbs.
EST. VALUE/POUND TERMINAL	$1.00	$0.80	$2.00	$2.00	$0.90
TERMINAL VALUE	$25,432	$42,240	$57,780	$69,108	$76,600
3% ASSES. VALUE	$1,872	$4,320			$14,175
COST RECOVERY VALUE	$27,304	$46,560	$57,780	$69,108	$90,775
TOTAL VALUE CPF & TERMINAL	$87,834	$186,240	$57,780	$69,108	$549,100

GENERAL DISCUSSION

(Where Do We Go From Here?)

MEMORANDUM

State of Alaska

DEPARTMENT OF FISH AND GAME

TO: Dave Cantillon
Region I Supervisor
Commercial Fisheries Division
Douglas

THRU:

DATE: May 4, 1987

FILE NO.:

TELEPHONE NO.: 465-4250

SUBJECT: Sockeye Workshop

FROM: Gary Gunstrom
Region I Research Supervisor
Commercial Fisheries Division
Douglas

Our recent regional sockeye review/workshop attracted 34 invited participants from two Department fisheries divisions, the two Southeast Alaska aquaculture associations, and the National Marine Fisheries Service. The day and a half meeting included 13 presentations and a general discussion period. I plan to produce the presentation summaries and discussion notes in a bound document early this summer. Comments received in regard to the workshop were very favorable.

A major area of concern identified during the workshop was that of sockeye escapement goals for the producing systems in the Region. This subject was the major focus of the General Discussion period and resulted in the designation of an Ad Hoc Committee to address sockeye escapements in S.E. Alaska. Fred Bergander of our shop and Mike Haddix, FREDD, were appointed as co-chairmen. Other members will include Steve Hoffman, Phil Dougherty, an as yet-to-be-named representative of the NMFS, and, perhaps, a user-group representative. The co-chairman will establish the committee's final core group membership and seek council, on an as-needed basis, from the Forest Service, the user groups, the Chief Fisheries Scientist Office, and other sources.

Mandates given to the committee were as follows:

1. Establish a methodolgy for addressing escapements.

2. Establish a methodolgy for addressing escapement goals.

3. Establish criteria for classification of the 120 producing systems in the Region into large, medium, and minor producers.

4. Classify systems in regard to water type, e.g., clear, glacial, organically stained.

5. Note systems with special import to the U.S./Canada Treaty.

6. Establish, where possible, desired escapement ranges.

Recognizing that little is known about the production potential of most of our sockeye systems, and the sensitive political nature of many of them, the committee was cautioned about establishing set numerical "goals" and, instead, was directed to address "desired (or optimum) escapement ranges". The committee is to present its report to the ADF&G fisheries division directors, through the respective regional supervisors, in December 1987.

It was further recommended during the General Discussion that given the interest and renewed emphasis on sockeye salmon in S.E. Alaska the regional sockeye review/workshop be an annual event to be held, preferably, in mid-winter.

The last item recommended during the General Discussion came from the NSRAA which asked that the State establish an inter-agency enhancement steering committee to address sockeye enhancement and wildstock needs, and coordinated actions in the Region. I noted that it was my understanding that such was a function of the Northern Southeast Regional Planning Team and that I would propose the subject for discussion at the next RPT meeting.

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cc: Fred Bergander
Mike Haddix
Phil Mundy